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SMOKE AS A SOURCE OF ATMOSPHERIC POLLUTION.*

BY

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I. INTRODUCTION.

THE presentation which follows is based upon investigations made in the city of Chicago during the past six years. The investigations have been the outgrowth of a popular belief that the atmosphere of Chicago has been more smoky than it needed to be, and that the steam locomotives of the Chicago railroads have been large contributors to the total smoke content of the atmosphere.

After much discussion in the City Council and elsewhere, the Chicago Association of Commerce, an organization devoted to the welfare of the city and in a peculiar sense representative of its business interests, undertook, in 1909, the direction of an educational movement in the abatement of smoke, and has since persisted in its efforts. It first appointed an expert committee to consider and report upon questions relating to the desirability and the practicability of electrifying the steam railway terminals of the city, and upon other questions relating to the elimination of smoke. This committee, in due time, presented a report containing a series of recommendations. Its conclusion with reference to the

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electrification of railroads was to the effect that such electrification was practicable from an engineering standpoint; that when effected it would be of economic advantage to the railroads; that it would present no greater element of danger than now exists; and that the most serious and difficult features of the problem were financial.

The railroads declined to accept the conclusions set forth by this report, and in stating their objections they emphasized the fact that the conclusions of the committee were merely the opinions of individual members; that the committee had made no investigations and was in possession of no information not available to others.

This attitude on the part of the railroad officials emphasized the desirability of a thorough investigation, which should determine the relative responsibility of the different fuel-consuming services for the smoke of the city, and the practicability of electrifying its steam-railroad terminals as a means in smoke abatement. It was finally agreed that if the Association of Commerce would provide for the organization of such an investigation, the cost of conducting it would be met by the railroads of Chicago.

In obedience to this arrangement, a second committee was appointed, which has since been known as the Chicago Association of Commerce Committee of Investigation on Smoke Abatement and Electrification of Railway Terminals. The committee thus formed, consisting of sixteen members, was organized for work in 1911. Four of its members were representatives of the city government and were nominated by the Mayor of the city of Chicago, four were railway presidents, and nine were representatives of the Association at large. Its purpose was early defined as follows:

> 1. To bring about a determination as to the necessity for changing the motive power of steam locomotives to electric or other power.
>
> 2. To determine the mechanical or technical feasibility of such a change.
>
> 3. To determine the financial practicability of such a change.

A chief engineer was appointed, and under his direction an expert staff was organized to conduct the necessary investigations. The work thus outlined has now been completed and the

report of the committee has been issued.[1] The methods employed by this committee in its investigations will be serviceable to those who may be called upon to investigate similar problems in other cities. Many of the conclusions which have been drawn may be accepted as of rather general application.

II. THE EFFECTS OF SMOKE AS THEY APPEAR IN LITERATURE.[2]

Smoke and soot are generally regarded as modern evils. They are not so in fact. Our first definite information of the use of bituminous coal is gained from complaints which were made against its use because of its smoke. In England, in the time of Edward the First, the nobility protested against the use of "sea-coal," and fifty years later a man is said to have been put to torture in London because he filled the air with a "pestilential odor" through his use of coal. In the middle of the fourteenth century the authorities of the German town of Zwickau proclaimed as law: "Know ye that all smiths working within the walls must refrain from the use of coal in their work." Toward the end of the eighteenth century many scientific and practical men, among whom are to be numbered the celebrated engineer, James Watt, and the distinguished and ever-active Benjamin Franklin, gave attention to problems arising in connection with the use of bituminous coal for domestic and industrial purposes.

In general, the prohibition of smoke ordinances relates to its visible aspect. Many American cities prohibit "dense smoke"; others, "black, thick, and continuous smoke"; and still others, "dense black or dense gray smoke." The city of Philadelphia attempts greater precision by specifying "smoke intercepting more than 60 per cent. of light, and fumes of sulphurous or noxious odor." Obviously, these terms are not precise. In many cases they have been found too elastic to sustain a proper enforcement of the ordinance. A comprehensive definition of smoke must take account of the process by which the smoke is produced, the

[1] "Smoke Abatement and Electrification of Railway Terminals in Chicago," a report of the Association of Commerce Committee of Investigation.

[2] Smoke as an element in the pollution of the atmosphere has been extensively studied. A list of articles consulted by the Chicago committee contains 450 entries.

nature and composition of its constituents, the manner in which this may be diffused in air, and the degree to which they may separately or collectively be regarded as injurious or objectionable.

The literature of the subject shows that the methods devised for studying the atmosphere of cities are still largely experimental. Although soot and its effects have formed the principal subjects of complaint, the methods commonly employed in determining the solid content of smoke-polluted air are admittedly less satisfactory than those used in determining the gaseous content. The fact is coming to be emphasized that effective smoke inspection must involve technical knowledge and the skilful use of laboratory equipment. Comparative studies of the air of neighboring cities based on such methods are being generally urged.

The influence of smoke in the atmosphere upon health constitutes a question which has been much discussed. The testimony as it appears in existing literature is conflicting. Doubtless many writers have been inclined to over-emphasize the effect of smoke upon health. A summary of such a review of this phase of the problem has been set forth as follows:[3]

1. There is a general agreement among sanitary authorities that polluted air is harmful to health.

2. At the present time there is no accurate method of measuring this harm, nor of determining the relative responsibility of the different elements which enter into the mixture of gases and solids commonly referred to as atmospheric air.

3. The direct effect of smoke or of any of its attributes, including soot, dust, and gases, in amounts which may ordinarily pervade the atmosphere of a smoky city, are not shown to be detrimental to persons in normal health.

4. The direct effect of smoke upon those who are ill has been most extensively studied in connection with tuberculosis and pneumonia. It appears that smoke does not in any way stimulate the onset of the tubercular process nor militate against the rapidity of recovery

[3] Report of the Chicago Committee of Investigation.

when once this disease has been contracted, but that it has a direct antiseptic effect and tends to localize the disorder. In cases of pneumonia the effect becomes seriously detrimental.

5. In addition to these direct results, indirect effects result from the diminution of sunlight and the increase in fogs, clouds, and haze.

The effect of smoke upon vegetation where the exposure is severe is clearly shown. The results of observations and experiments touching this phase of the matter have been summarized as follows:[4]

1. That smoke may exert injurious effects on vegetation. These effects may be direct or indirect. The direct effects are slow in asserting themselves, trees and plants exposed to them gradually losing vigor through a series of years until they finally perish.

2. That the products of combustion which are most pronounced in their direct effects are the soot and tar discharges and the sulphurous gases, though injury may occur as a result of an increased acidity in the soil caused by smoke.

3. That the indirect effects appear as a result of fogs induced by smoke, the occurrence of which has sometimes injured or destroyed tender plants.

4. That no basis is supplied upon which to judge the amount of smoke which is necessary to bring about injurious results; the effects described are generally such as have attended exposure to severe conditions.

The loss and damage to property arising from smoke has been tentatively studied in various localities, and estimates based upon fuel consumption have been made. In none of these can the methods be accepted as satisfactory or the results as approximating the truth. Many of the facts involved are variable or indeterminate. It may be noted that:

1. The loss and damage caused by the gaseous products of combustion are due chiefly to their sulphur con-

[4] Chicago Committee of Investigation.

tent. The investigations of the Chicago Committee show that the extent to which sulphur appears in such gases depends upon the composition of the fuel and not to any great extent upon the manner in which it is burned. Loss and damage, therefore, arising from the gaseous products of combustion are a function of the kind and quantity of fuel burned.

2. The extent of loss and damage arising from the solids in smoke will, other things being equal, depend upon the character of the solids. For example, solids in the form of soot and oily distillates of fuel soil and deface more quickly than solids in the form of coke or ash particles. The former are characteristic of smoke from low-temperature fires, such as those of domestic service; the latter are characteristic of smoke from high-temperature fires, such as those of high-pressure steam boilers and steam locomotives.

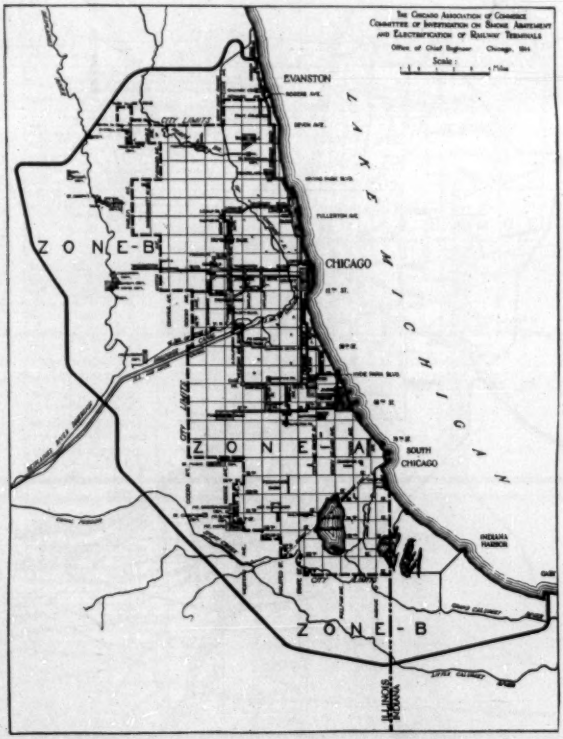
An attempt to define the extent of losses regardless of the manner in which they arise at once discloses the lack of a definite or reliable standard of measure. It can not be assumed, for instance, that a large city ought to be as clean as a country village, nor can any ratio of cleanliness be established. It is obvious that the diversified activities of the larger communities are productive of a greater degree of street dust and other forms of atmospheric pollution, as well as of smoke, than those of small towns. The large cities are, in most cases, more congested than the small ones, and this congestion is in itself productive of a greater degree of atmospheric pollution, whether of a preventable or unpreventable nature. In view of the many complex and variable factors involved, any attempt to secure a satisfactory estimate of the financial loss occasioned by city smoke must be more elaborately organized and conducted than any which has thus far been undertaken.

III. THE CITY OF CHICAGO.

Since the discussions which follow concern results which are applicable to the city of Chicago, some brief description of that city must be given.

The fact is clearly recognized that the activities of the city and of its suburbs so intermingle that the interests of residents of city and suburbs are in many respects common. Moreover,

FIG. 1.



The committee's Area of Investigation, emphasizing location of parks and boulevards.

smoke in the atmosphere is easily transferred from city to suburb and from suburb to city. Such considerations lead to the inclusion of considerable territory which is outside of the city in the com-

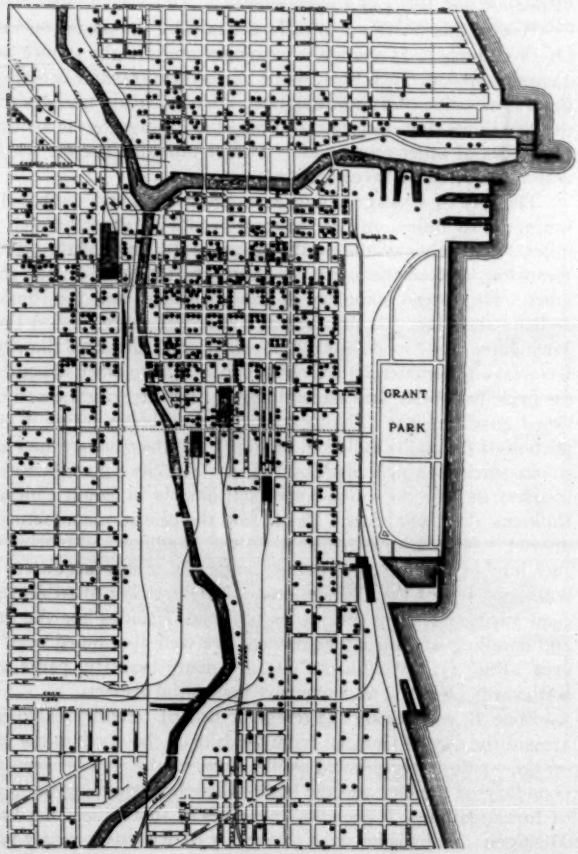
mittee's area of investigation. This area is represented on the official maps of the committee (Figs. 1 and 2) as that which lies between Lake Michigan and the heavy black boundary line.

FIG. 2.

The committee's Area of Investigation, emphasizing location of railroads.

For convenience this area has been divided into two parts, Zone A comprehending the area of the city, and Zone B the area of outlying territory. Zone A includes 194.4 square miles;

FIG. 3.



Section of map showing high-pressure steam boiler plants in Chicago.

Zone B, 233.9 square miles, and the whole Area of Investigation (Zones A and B), 428.3 square miles.

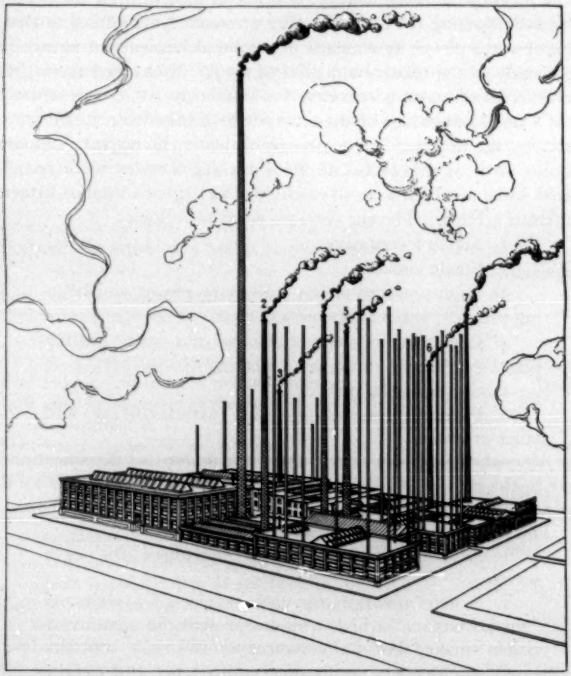
Within this territory 39 different railway companies operate. Of this number, 25 maintain passenger and freight service and 23 are classed as trunk lines, while 14 perform transfer or switching service only. Of the trunk lines, 8 have no main tracks within the city limits, but operate trains into the Chicago terminals over the tracks of other companies. Twelve railroads operate wholly within the Area of Investigation.

The city of Chicago, Zone A, extends north and south a distance of 26 miles, and its average width is approximately 8 miles. It touches on the north the corporate limits of the city of Evanston, and on the south the open prairies beyond Lake Calumet. Its eastern boundary is Lake Michigan and the Illinois-Indiana state line. It presents 23.4 miles of shore line on Lake Michigan. Its "loop district," in which are centralized the city's financial and commercial activities, contains lofty office structures, the principal hotels, and the buildings of the city, county, and national governments. The location of steam-boiler plants in this portion of the city is indicated by Fig. 3 and the chimney flues and smoke-stacks of single block by Fig. 4. The city's manufacturing districts include the extensive establishments in South Chicago, Pullman, the Union Stock Yards, and the central manufacturing district. Its industries engaged in the handling and storing of fuel, lumber, and of other building materials, occupy large areas on both branches of the Chicago River. Its network of steam railroad yards, its shops and other terminal facilities for the care and handling of railroad equipment are well distributed over its area (Fig. 2). Within the city are many beautiful parks and boulevards (Fig. 1), and extensive residential districts.

Zone B, comprising the irregular belt of territory extending around the city of Chicago from the lake on the north to the lake on the south, is represented on the maps as the area between the boundary of the city and the heavy black line bounding the Area of Investigation. It presents 12.9 miles of shore line along Lake Michigan. It includes most of the city of Evanston, nearly two-score suburban villages in Illinois, and the manufacturing cities of Hammond, Whiting, and East Chicago in Indiana; it contains also

extensive areas of unimproved land. It is traversed by all railroads entering the city, and is occupied by many large railroad yards, such as those at Godfrey, Proviso, Clearing, and Dolton in

FIG. 4.



A typical block in the business district of Chicago in which the actual buildings are assumed to give way to buildings of factory height and in which the existing smokestacks and chimneys are assumed to remain at their present heights. The drawing is an isometric projection. The numbers indicate power plant stacks.

Illinois, and those at Gibson and Kirk in Indiana. From the standpoint of railroad activity, Zone B is the hinterland of the city. Trunk and belt lines make it common ground upon which to inter-

change cars entering or leaving Chicago, as well as those destined to points beyond.

IV. FUEL CONSUMPTION IN CHICAGO.

The purpose of the Chicago committee to determine the necessity for changing the motive power of steam locomotives to electric or other power as a means in smoke abatement led naturally to a study of the relative amounts of smoke discharged from different fuel-consuming services, for obviously, if it were shown that a small percentage of the total smoke comes from steam locomotives, the necessity for a change could not be urgent. In the development of this phase of the work six services were recognized, some of which were so subdivided as to give a total of fifteen different groups. The six services were as follows:

1. Steam locomotives.
2. Steam vessels.
3. High-pressure steam stationary power and heating plants.
4. Low-pressure steam and other stationary heating plants (including all domestic heating).
5. Gas and coke plants.
6. Furnaces for metallurgical, manufacturing, and other processes.

All coal consumed was accounted for under this classification; that is, the sum of coal burned in the several services is the total consumption within the Area of Investigation.

The further procedure involved:

1. A determination of coal consumed for each service.
2. A determination for each service of a series of "smoke factors" which would represent the amount of visible smoke, the solid constituents of smoke, and the gaseous products of combustion emitted, per unit weight of coal burned.
3. The combination of the amounts of coal burned in each service with the approriate smoke factors in such manner as to give a relative measure of the smoke discharged by each service.

The fuel consumption for the year 1912 was determined

through the coöperation of many different agencies. All common carriers (railroads and boat lines) made monthly reports throughout the year of their deliveries of revenue coal within the committee's Area of Investigation. While the methods of reporting varied, most carriers made returns from each point of delivery, with the result that many thousands of individual reports were handled by the committee. Coal brought in as company freight was determined as the result of a carefully-conducted investigation. Variations in the amount of coal in store and the extent to which these amounts were affected by reshipments were taken into account. A summary of results thus obtained, applicable to the committee's Area of Investigation, is set forth as follows:

	Tons	Total
Coal and coke delivered by rail as revenue freight	17,563,711	
Coal and coke delivered by boat as revenue freight	1,706,356	
		19,270,267
Coal and coke consumed by steam locomotives in service..	2,555,233	
Coal and coke consumed by steam locomotives at locomotive terminals	260,167	
		2,815,400
Coal and coke consumed by railroad stationary plants....		524,596
Coal and coke consumed by steam vessels within the Area of Investigation		92,368
Decrease in amount of fuel in storage		231,041
		22,933,672
Deductions:		
Coal and coke delivered to steam vessels but not consumed within the Area of Investigation	126,556	
Coal and coke reshipped from points within the area to points within and points outside the area	800,413	
Coal equivalent of the fuel and by-products produced by gas and coke plants	797,817	
		1,724,786
Net total		21,208,886

The origin of the coal consumed within the Area of Investigation is as follows:

Kind of Fuel	Origin	Tons	Per cent. of total
Anthracite	Pennsylvania	1,827,158	8.62
Pocahontas *	West Virginia	1,230,787	5.80
Coke	Various states	3,435,753	16.20
Bituminous	Illinois	9,184,126	46.31
Bituminous	Indiana	3,084,688	14.54
Bituminous	Other states	2,446,374	11.53
Totals		21,208,886	100.00

The consumption of solid fuels for the year 1912 within the Area of Investigation by services was as follows:

	Tons
Steam locomotives	2,815,400
Steam vessels	92,368
High-pressure stationary power and heating plants	9,147,334
Low-pressure steam and other stationary heating plants	4,646,910
Gas and coke plants	253,867
Furnaces for metallurgical, manufacturing and other processes	4,253,007
Total	21,208,886

The consumption of solid fuels within the limits of the city of Chicago (Zone A) for the year 1912 was as follows:

	Tons
Anthracite	1,633,002
Pocahontas	1,174,742
Coke	3,099,302
Bituminous (all services)	11,675,477
Total	17,582,523

The consumption of solid fuels within the city (Zone A) for the year 1912, by services, was as follows:

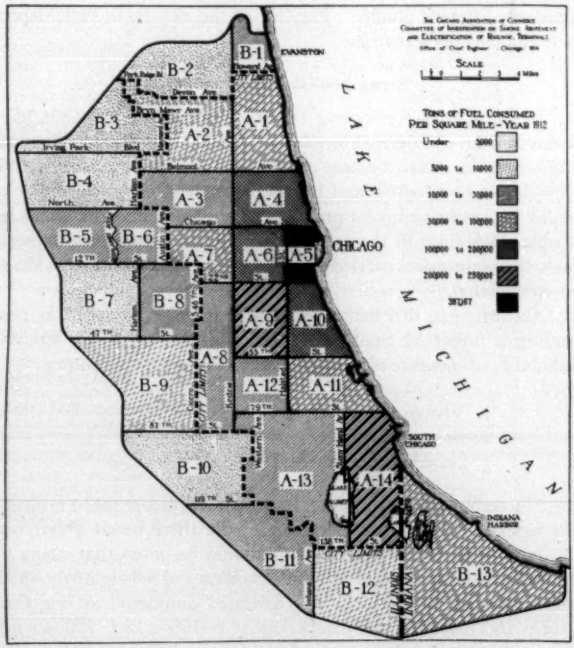
	Tons
Steam locomotives	2,099,044
Steam vessels	81,375
High-pressure stationary power and heating plants	7,316,257
Low-pressure steam and other stationary heating plants	4,154,746
Gas and coke plants	234,551
Furnaces for metallurgical, manufacturing, and other processes	13,696,550
Total	17,582,523

*It has not been possible to determine the degree of accuracy attending the use of the term "Pocahontas" in the reports received through different agencies. It is probable that as here used it applied to any semi-bituminous coa from the West Virginia region.

The density of fuel consumption for different district areas is set forth by Fig. 5.

In addition to the solid fuels consumed, it is estimated that there were used within the committee's Area of Investigation dur-

FIG. 5.



Relative density of fuel consumption in the several zone districts.

ing its statistical year appproximately 3,511,000 barrels of fuel oil, chiefly in industrial fires. This amount of oil is equivalent to 1,170,000 tons of coal, or to about 5½ per cent. of the city's annual consumption of solid fuel. The amount of kerosene consumed,

chiefly in lighting, amounted to 231,579 barrels, and the amount of gasoline and naphtha used, chiefly for automobile engines, amounted to something more than a half million barrels.

These figures serve to disclose the enormous quantities of fuels consumed within the Area of Investigation. It is obvious that the coal-consuming industry touches the activities of the municipality at many different points. The life of the city is, in fact, dependent upon its preservation.

V. THE PROPERTIES OF SMOKE.

Investigations concerning the so-called smoke nuisance have hitherto dealt chiefly with smoke as a visible pollution. The Chicago committee early became convinced that a more general definition should be adopted, and for its own purpose it defined smoke as the "gaseous and solid products of combustion, visible and invisible, including, in the case of certain industrial fires, mineral and other substances carried into the atmosphere with the products of combustion."

According to this definition, smoke may be regarded as possessing a threefold character, to each aspect of which suitable standards of measure may be applied. These are as follows:

1. Visible properties.
2. Solid constituents.
3. Gaseous constituents.

The committee's procedure, by which it was sought to evaluate the smoke of different services under the three heads given, can not here be given, though the fact should be noted that many of its methods were original and that its office and field staff to which this aspect of the problem was assigned numbered at one time nearly 100 men. In the discussion of results which follows numerical facts will only be given for the city of Chicago (Zone A).

VI. VISIBLE SMOKE IN CHICAGO.

The relative standing of different services with reference to visible smoke within the limits of the city of Chicago has been set forth by the committee, as follows:

RELATIVE AMOUNT OF VISIBLE SMOKE PRODUCED BY EACH SERVICE, AS DETERMINED BY THE RINGELMANN METHOD.

Zone A (The City of Chicago).

Service	Fuel consumed, tons	Average smoke density, per cent.	Relative standing, per cent.
Steam locomotives:			
Yard	1,049,516	16.73	10.25
Road freight	136,115	25.32	2.01
Freight transfer	354,802	22.16	4.59
Passenger transfer	21,370	15.11	0.19
Through passenger	176,761	20.09	2.07
Suburban passenger	155,327	17.03	1.54
Locomotive terminals	205,153	11.77	1.41
Totals	2,099,044	.....	22.06
Steam vessels:			
Tugs and lighters	35,153	14.04	0.29
River barges, dredges, pile-drivers, etc.	10,525	22.99	0.14
Lake steamers and barges	35,697	14.79	0.31
Totals	81,375	.....	0.74
High-pressure steam stationary power and heating plants, including: Public service corporation plants, Municipal plants, Steam railroad plants, Office buildings, hotels and schools, Manufacturing plants	7,316,257	10.42	44.49
Low-pressure steam and other stationary heating plants, including: Large and small buildings, Large and small apartments, Residences	4,154,746	1.62	3.93
Gas and coke plants:			
Public service (not including boiler power plants)	139,525	0.00	0.00
Other service (not including boiler power plants)	95,026	2.69	0.15
Totals	234,551	.....	0.15
Furnaces for metallurgical, manufacturing, and other processes, including: Steel plants, foundries, forges, and allied processes (not including boiler power plants), Brick, pottery, and allied processes, Miscellaneous manufacturing, rendering, and other processes	3,696,550	13.27	28.63
Grand totals	17,582,523	.....	100.00

The results are of interest from many points of view. They show that nearly half of the total visible smoke is made by high-pressure steam stationary plants; that such plants and industrial fires combined make three-quarters of the total smoke, and that the railroads make approximately one-fifth of the total smoke. In view of the relative extent of the railroad establishments in Chicago, it would appear that the percentage of railroad smoke in the atmosphere of that city would be at least as great as that in the atmosphere of other large American cities.

Visible smoke arising from the burning of bituminous fuels is the result of a failure, either in the design of the furnace or in its operation, to observe certain conditions which are the necessary accompaniments of so-called "smokeless" combustion. These conditions may be summarized briefly as follows :

1. The coal must be introduced into the furnace at such a point and distributed in such a way that the gases distilled from it will be required to pass over or through the incandescent portions of the fire. The observance of this condition will, in most cases, expose the distillates to a temperature sufficiently high to insure their ignition. These distillates, if not burned, are prolific sources of visible smoke.

2. The stream of gases from the fuel must be heated quickly and kept at a high temperature until the process of combustion is well advanced. The presence of a fire-brick arch under which the distillates may be burned, and the passing of the distillates through the bed of fire, are aids in securing this condition.

3. The avoidance of heat-absorbing surfaces in close proximity to the burning distillates, the interposition of which tends to cool the gases, to suppress combustion, and to produce visible smoke.

4. The admission of air, by which combustion is stimulated, should be provided for at proper points and should be carefully regulated.

5. The proportions of the furnace should be such as will provide an ample flameway or combustion chamber. The observance of this condition is necessary in order that the time occupied by the gases in passing through the furnace may be sufficient to permit them to burn completely.

If all of these conditions are observed, the smoke arising from fires of bituminous coal will be nearly, if not wholly, invisible, but there are many practical difficulties to be met by one who seeks to observe them; as a consequence, the products of combustion issuing from bituminous coal fires are commonly more or less visible.

The importance of the flameway in relation to visible smoke is at once apparent. Fuels burn with different lengths of flame, depending upon their composition. For example, coke and anthracite coal, the principal combustible element of which is carbon, burn with a very short flame. The whole process of combustion takes place at or near the surface of the fuel. Such fuels can be burned without developing visible smoke, even though the flameway may be short and otherwise restricted.

The bituminous coals of Pennsylvania and Ohio are relatively lower in carbon and higher in volatile matter than coke or anthracite coal, and the volume of gases distilled from them is greater. The process of intermixing and combining the combustible gases thus distilled with the air necessary to their combustion takes an appreciable period of time; hence the flame is comparatively long and the furnace must be such as to supply room in which combustion may proceed.

The bituminous coals of Illinois are higher in volatile matter than are the bituminous coals of Pennsylvania and Ohio, hence they require a still longer flameway.

The temperature of the flameway is also important in its relation to visible smoke. It is because of low temperatures that the bituminous coal fires of stoves and small furnaces, receiving attention at infrequent intervals, are sometimes prolific sources of visible smoke. A large mass of Illinois coal placed upon the surface of a fire at once lowers the furnace temperature to such a degree that the distillates which come from the fresh coal pass off without igniting. Progress in the art is steadily finding new means, by the application of which a satisfactory temperature even of a small fire may be maintained. In the development of such means the brick arch has had an important part.

Furnace draft is important in its relation to visible smoke. Draft is the governor controlling the rate of combustion. If the draft is weak, the rate of combustion will be low and the temperature of the fire may be lower than that which is necessary for the

suppression of visible smoke. A strong draft also stimulates the activity of the intermixing currents in the furnace and so aids combustion. Strong drafts normally imply high rates of combustion and high furnace temperatures, so that, in general, it may be said that the abatement of visible smoke is promoted by increasing the draft of the furnace. Here again the solution of the problem is comparatively easy in its application to large fires and extremely difficult in its application to small fires.

Air supply is important in its relation to visible smoke. Perfect combustion implies that all of the carbon in the fuel shall have an opportunity to combine with oxygen. The oxygen needed for this purpose is supplied by the air which is borne into the furnace by the action of the draft. If the supply of air is deficient, the burning process will be incomplete and visible smoke will result. To avoid such an occurrence, it is customary to provide for a larger supply of air than is needed to support combustion, and, under some conditions, the excess supply is very large. While it sometimes happens that an excessive supply of air tends to lower the temperature of the fire, to cool the flameway, and, under certain conditions, to increase the visible smoke, the fact remains that up to a certain limit, which may vary with the construction of the furnace, increasing the air supply aids in reducing the visible smoke.

No one thing has been more potent in contributing to the elimination of visible smoke than the advent of mechanical stokers and other forms of automatic furnaces. These devices represent results achieved in the development of furnace design to meet the requirements of theoretical conditions. Their introduction implies not only automatic feeding, but the acceptance of other conditions essential in the elimination of visible smoke. Mechanical stokers provide for the progressive movement of the fuel into the furnace; they generally provide for an ample flameway and a brick arch under which the initial combustion may proceed. They are rarely installed except where satisfactory draft conditions are assured; as a consequence, it is commonly assumed that the mechanical stoker or hopper-fed furnace is a smoke-abating device, and in general this assumption is justified. This statement does not imply that mechanical stokers or other devices for automatic stoking will in themselves suffice to make smoke invisible. It is only when they are properly operated that they can be depended upon to give satisfactory results.

The investigations of the Chicago committee are impressive in the testimony they yield as to the value of care in firing as a means of reducing visible smoke. This statement applies, whatever may be the form of furnace used or apparatus employed. Careless hand-firing results in large volumes of visible smoke; careful, frequent, and progressive hand-firing results in the elimination of most of this smoke. The careless manipulation of the automatic stoker may result in the production of visible smoke; its careful handling will suffice to eliminate most of this smoke. A comparison of the smoke arising from any coal-consuming service, as maintained within the city limits of Chicago where its operation is subject to municipal inspection, with that arising from the same class of service outside the city where no restrictions are imposed, will disclose a lower density of smoke within the city than outside. That is, where it is necessary to reduce the visible smoke, the attention needed to secure such a result is given; where it is not necessary, the effect of neglect is to be seen in the result.

Smoke abatement is often an indirect means of effecting economy. While the constituents of smoke which impart visibility to it represent a relatively small amount of heat, and while, as a consequence, no great saving can be directly effected through the suppression of visible smoke, it is nevertheless true that the process of smoke suppression may open channels through which important benefits may accrue. For example, the suppression of smoke implies the substitution of good for poor fire-room practice. If the fire-room is large, smoke abatement implies the use, the proper maintenance, and the skilful manipulation of automatic firing devices. If the fire-room is small, it implies the exercise of superior skill and intelligence on the part of the fireman. In general, smoke suppression involves a reorganization of fire-room administration and methods, and a reorganization stimulated for the purpose of reducing smoke opens the way to other reforms, the net effect of which may constitute a material saving in the operation of the plant.

VII. THE SOLID CONSTITUENTS OF CHICAGO SMOKE.

The contributions of the different fuel-consuming services to the solid elements of atmospheric pollution for the city of Chicago have been set forth by the committee as follows:

AMOUNT OF SOLIDS EMITTED IN SMOKE FROM EACH SERVICE AND RELATIVE STANDING OF SERVICES.

Zone A.

Service	Fuel consumed		Solids in smoke		
	Kind	Tons	In per cent. of fuel consumed	Tons	Per cent. of total
1	2	3	4	5	6
Steam locomotives:					
Yard	Pocahontas	23,049	1.778	410	0.14
	Bituminous	1,026,467	0.471	4,835	1.59
Road freight	Bituminous	136,115	2.642	3,596	1.18
Freight transfer	Pocahontas	2,996	1.470	44	0.01
	Bituminous	351,806	0.362	1,274	0.42
Passenger transfer	Pocahontas	885	1.778	16	0.01
	Bituminous	20,485	0.471	96	0.03
Through passenger	Pocahontas	2,441	3.116	76	0.02
	Bituminous	174,320	3.116	5,432	1.78
Suburban passenger	Bituminous	155,327	3.866	6,005	1.97
Locomotive terminals	Bituminous	205,153	0.471	966	0.32
Totals		2,099,044	1.084	22,750	7.47
Steam vessels:					
Tugs and lighters	Anthracite	112	0.223	*	†
	Pocahontas	3,748	1.290	48	0.02
	Bituminous	31,293	1.222	382	0.12
River barges, dredges, etc.	Pocahontas	1,186	1.290	15	0.01
	Bituminous	9,339	1.222	114	0.04
Lake steamers and barges	Bituminous	35,697	1.222	436	0.14
Totals		81,375	1.223	995	0.33
High pressure steam stationary power and heating plants:					
Public service, municipal, steam railroad, office buildings, schools, hotels & manufacturing	Anthracite	5,291	0.223	12	†
	Coke	2,121	0.223	5	†
	Pocahontas	262,196	0.649	1,702	0.56
	Bituminous	7,046,649	0.811	57,148	18.78
Totals		7,316,257	0.805	58,867	19.34
Low-pressure steam and other stationary heating Plants:					
Buildings, apartments and residences	Anthracite	1,577,761	0.138	2,177	0.71
	Coke	41,181	0.223	92	0.03
	Pocahontas	849,185	0.490	4,161	1.37
	Bituminous	1,686,619	1.171	19,750	6.49
Totals		4,154,746	0.630	26,180	8.60

AMOUNT OF SOLIDS EMITTED IN SMOKE FROM EACH SERVICE AND RELATIVE STANDING OF SERVICES.

Zone A.—Continued.

Service	Fuel consumed		Solids in smoke		
	Kind	Tons	In per cent. of fuel consumed	Tons	Per cent. of total
1	2	3	4	5	6
Gas and coke plants (exclusive of boiler power plants):					
Public service	Anthracite	5,882	No tests made		
	Coke	133,643			
Other service	Anthracite	245			
	Pocahontas	2,366			
	Bituminous	92,415			
Total		234,551			
Furnaces for metallurgical, manufacturing, and other processes (exclusive of boiler power plants):					
Steel plants, foundries, forges, and allied processes	Anthracite	31,442	1.798	565	0.19
	Coke	2,909,360	6.380	185,617	60.98
	Pocahontas	26,368	1.290	340	0.11
	Bituminous	651,187	1.084	7,059	2.32
Totals		3,618,357	5.350	193,581	63.00
Brick, pottery and allied processes	Coke	206	1.798	4	†
	Pocahontas	0	0	0	†
	Bituminous	8,165	15.560	1,270	0.42
Totals		8,371	15.219	1,274	0.42
Miscellaneous manufacturing, rendering and other processes	Anthracite	12,269	0.223	28	0.01
	Coke	12,791	1.798	230	0.07
	Pocahontas	322	1.290	4	†
	Bituminous	44,440	1.084	482	0.16
Totals		69,822	1.066	744	0.24
Sub-totals		3,696,550	5.291	195,599	64.26
Grand totals		17,582,523	1.731	304,391	100.00

* Less than 0.5 ton.
† Less than 0.005 per cent.

It will be seen that the greatest contributors to this form of atmospheric pollution are the industrial fires; that stationary boiler plants are relatively large contributors, and that steam locomotives contribute a relative small percentage of the total.

The polluting effects of the solid constituents of smoke are dependent to some extent upon their chemical composition. The presence of hydrocarbons is generally more objectionable than the presence of mineral matter or unconsumed carbon. Hydrocarbons constitute a large proportion of the distillates of coal. They appear in the atmosphere in the form of soot, which readily soils and blackens. Soot is easily transported by air currents. Any service, therefore, the smoke of which is high in hydrocarbons constitutes a more objectionable source of atmospheric pollution than a service the smoke of which is low in such distillates.

Not all of the solids in smoke are of fuel origin, though, for purposes thus far set forth, it is assumed that solids passing out of chimneys with the products of combustion may be regarded as solid constituents of smoke. Since the investigation was for the purpose of determining the relative contributions of different fuel-consuming services to the total quantity of dust in the atmosphere, this assumption is not misleading, and it has the advantage of supplying a definite basis upon which conclusions may be established. Its effect, however, has been to emphasize the importance of certain metallurgical and other industrial fires which send out with the products of combustion a heavy lading of metallic or mineral dust. Fires which are sustained by coke and by fuel gas, as well as those which are sustained by coal, may, upon this basis, be prolific producers of dust.

The amount and character of the solid constituents of smoke, so far as they are of fuel origin, are functions of furnace conditions. The path of the solids is that which is followed by the currents of air and gases; these currents enter the furnace through the bed of fire, and, passing along the flameway, enter by whatsoever channel may be provided into the smokestack, from which they pass on to the atmosphere. A weak draft, such as that which normally prevails in connection with domestic fires, implies fine dust particles and soot flakes only in the smoke, whereas a strong draft, such as that which commonly prevails in boiler plants served by lofty chimneys and in steam locomotives, implies the discharge of solid particles of considerable size.

Changes in the rate of combustion produce changes in the temperature of the fire and in the character of the solids in smoke. Low draft values imply low rates of combustion, low furnace temperatures, and solids in smoke consisting largely of particles

condensed from distillates driven out of the freshly-applied fuels while in the process of being heated to the point of ignition. The solids include also very fine particles originating in the fuel and its ash which are sufficiently light to be borne away upon the current of the feeble draft. It is an interesting fact, as disclosed by the results of the committee's investigations, that, while the individual particles discharged from fires of low temperature may be small, the percentage of the coal burned which is represented by the hydrocarbons and soot passing off with the smoke is relatively high. It is because of this high percentage of hydrocarbons that the solid constituents of smoke emitted from fires of low temperature constitute an important factor in the total pollution of the atmosphere of a city.

High rates of combustion imply high furnace temperatures and smoke low in hydrocarbons and relatively free from soot. Solids from such fires include particles of partially-consumed fuel which, in the processes of the furnace, are exposed to the action of a draft too strong to permit them to retain their place on the fire-bed. They include portions of fine ash which are readily caught up and carried away, also spherical slag particles picked up from the fire-bed in a liquid state and solidified as they pass on their course into the atmosphere. The solid constituents of Illinois coal, when this coal is consumed in fires of high temperatures, yield a considerable percentage of these spherical slag particles, varying in size from those which are microscopic to others approaching one-eighth of an inch in diameter. All such particles have a honeycomb structure and, when crushed under foot or by traffic in the streets, yield a fine powder which is easily borne away upon the wind.

An important fact clearly defined by the investigations of the committee, the significance of which has not before been generally appreciated, concerns the omnipresence of solids in smoke discharges. As shown in the preceding sections, the quantity and character of the solids in smoke may vary greatly, but smoke arising from solid fuels is never free from such solids. Again, the amount of solids discharged has no direct relation to visibility. A stack may appear smokeless to the eye and yet be the source of a heavy discharge of fuel dust. The adoption of anthracite coal or of coke as a fuel will serve to make stack discharges invisible, but will not eliminate the dust discharge.

VIII. GASEOUS CONSTITUENTS OF SMOKE IN CHICAGO.

The limited significance which can be assigned to the facts makes it unnecessary to present in this connection a detailed statement of the gaseous products of combustion discharged by different fuel-consuming services.

Notwithstanding the large volume of gaseous products of combustion which are emitted into the atmosphere of a city, little trace of them is disclosed by a chemical analysis of the atmosphere. The explanation is, of course, to be found in the fact that, while the volume of the polluting discharge is great, that of the atmosphere is vast, and its power to absorb and diffuse the streams of pollution which enter it, great. The following illustration will prove serviceable in increasing one's understanding of this aspect of the matter.

The total volume of air-diluted gases discharged each day from the stacks of Chicago amounts approximately to 47,000,000,000 cubic feet. The average wind velocity recorded in the city during the year 1912 was 13 miles an hour. The area of the city is 194 square miles. Assuming that the diluted gaseous products of combustion rise uniformly over this area as from an orifice and are borne away in a horizontal film by the wind, the thickness of the film at any given time would be approximately one-third of an inch. But the smoke discharges making up this film are air diluted; if the air is extracted the thickness of the film would be reduced by 75 per cent.; that is, the film of the gaseous products of combustion becomes approximately eight one-hundredths of an inch in thickness. It will, of course, be understood that no such film actually exists, since the diffusion of the products of combustion into the atmosphere begins as soon as they are discharged; but the capacity of the atmosphere to absorb these gases can be better comprehended when one considers that its duty is that of continuously absorbing through diffusion a horizontal film of the gaseous products of combustion less than one-tenth of an inch in thickness.

IX. ALLIES OF SMOKE IN ATMOSPHERIC POLLUTION.

Thus far in the discussion of atmospheric pollution attention has been given only to smoke, but not all that pollutes the atmosphere is of fuel origin. Dust from many sources mingles with that of smoke to make up the sum-total of the dust content of Chicago's atmosphere.

If all the fires of a city were stopped, dust and dirt would remain in its atmosphere. When the atmosphere is dry and the wind velocity high, the air is filled with dust particles. This manifestation is not confined to the streets, for dust finds its way into buildings from which it must be removed by cleaning processes.

Atmospheric pollution can not be reduced to a minimum through attention to smoke abatement alone. In order to accomplish its reduction, attention must be given to all of those processes and activities of the city which give rise to dust or which deal with the collection and disposal of city dirt and waste.

The amount of city dust is a function of efficiency in city sanitation. It depends upon standards of cleanliness observed in the maintenance of streets and alleys and upon methods employed in cleaning them. It is important, therefore, in considering means to be employed in reducing the atmospheric pollution of the city, to give due attention, not only to smoke, but to all other sources from which city dust arises.

Some of the primary sources of atmospheric dust are bare-ground areas, including unimproved streets and alleys, fuel and building materials stored and in transit, building operations, street construction and repairs, the abrasion of streets and sidewalks under traffic, and back-yard and roof accumulations and activities. Secondary sources appear in conditions which permit dust, once settled from the atmosphere, to be redistributed by the wind.

X. ATMOSPHERIC POLLUTION AS DISCLOSED BY A STUDY OF THE ATMOSPHERE.

Paralleling its studies of fuel consumption and of smoke discharges, the Chicago committee undertook:

1. A study of the meteorological conditions in Chicago and in other cities, that the relation between meteorological conditions and atmospheric pollution might be shown.

2. A study of the atmosphere of cities as disclosed by a review of scientific literature bearing upon the subject.

3. An extensive examination of the atmosphere of Chicago involving filtration tests and chemical analyses of air samples drawn from many different parts of the Area of Investigation.

The filtration tests and analyses of air were made by means of a portable laboratory mounted upon a suitable motor truck, the equipment of which was so arranged that the laboratory might take up any predetermined location from which it could draw samples of atmospheric air continuously for a period of several hours' duration. This laboratory was kept in operation for a full year.

The results obtained from the study of the atmosphere justify certain general conclusions, some of which are as follows:

1. Wind movement has the effect of dissipating the polluting constituents of the atmosphere and of rendering them less objectionable. The extent to which products of combustion are effective in polluting the atmosphere may be said to vary inversely as the velocity of the wind.

2. Temperature as a factor in atmospheric pollution is of indirect importance only; it exerts an influence upon other atmospheric conditions, such as wind and humidity, which are factors of great importance. This relationship between temperature and other conditions is, however, complex.

3. High relative humidity serves directly to intensify the effects of atmospheric pollution, in that it promotes the formation of fogs or mists which hold the products of combustion in the atmospheric strata near the earth.

4. Precipitation is an effective purifier of the atmosphere. It operates to wash out a large portion of the polluting substance suspended in the air.

5. Sunshine, as affected by atmospheric pollution, serves as an indirect measure of the extent of the pollution.

6. In general, the combination of meteorological conditions which tends to intensify the effects of polluting substances in the air includes low wind velocity, comparatively low temperature, high relative humidity, and absence of sunshine.

7. Chicago's weather conditions, in their relation to the maintenance of a pure and wholesome state of the atmosphere, are far superior to those of most other cities of the United States and Europe.

8. In general, those polluting constituents of the atmosphere which are regarded as being most objectionable consist largely of solid particles which serve to soil or injure buildings and materials of every sort. These constituents have their origin largely in the combustion of fuel, and appear in the form of distillates of coal, unconsumed carbonaceous material, or ash. Ash in the atmosphere is practically devoid of color, and its presence is not readily identified. It is not as detrimental or apparent in its effect upon material objects as are the sooty or carbonaceous materials.

9. The quantity of solid materials in the atmosphere of Chicago varies from 0.321 to 1.958 milligrammes per cubic metre. Values of record for other cities are not numerous.

10. The solid materials or particles present in the atmosphere of Chicago include not only solid products of combustion, but also mineral, vegetable, and animal *débris*. The evidence based upon atmospheric analyses is to the effect that all sources of dust contribute to the pollution of the atmosphere.

11. The content of carbon dioxide in the atmosphere of cities, as disclosed by the reports of many investigations, does not appear to vary materially. The values determined for this substance, from samples taken of Chicago's atmosphere, correspond very closely to those reported for other cities.

13. Carbon monoxide, while in itself a poisonous gas, does not ordinarily constitute an important element in atmospheric pollution. No determinations of this gas were made in connection with the air analyses in Chicago. Values resulting from tests conducted in Paris and in Berlin indicate its presence only in minute quantities.

13. The ammonia content of the atmosphere of Chicago is small. The values reported for other cities are many times greater than those for Chicago.

14. Chlorine is not present in the atmosphere of Chicago in sufficient quantities to have any significance except as an indication of local conditions.

15. The gaseous compounds of sulphur are products

of combustion, and in the atmosphere of Chicago they vary from a minimum of 0.217 to a maximum of 1.104 milligrammes per cubic metre. The values reported for other cities, so far as obtainable, are generally higher.

16. Sulphur compounds, which eventually are converted into sulphuric acid, are, from the standpoint of atmospheric pollution, the most objectionable gaseous products of combustion. Sulphuric acid tends to exert an important influence in the disintegration of building materials of all kinds, and produces deleterious effects upon furnishings, clothing, and merchandise.

17. With reference to the geographical distribution of polluting substances in Chicago's atmosphere, it may be stated conclusively that the pollution is greatest in those localities where the greatest industrial activities prevail. The atmosphere in the loop district and in the neighborhood of railroad terminals is more seriously polluted than that of outlying districts.

18. The polluting constituents of the atmosphere have their origin in many kinds of industrial activity. Of the solid elements of pollution in the atmosphere of Chicago, not more than two-thirds of the total is of fuel origin.

XI. ELECTRIFICATION AS A MEANS IN SMOKE ABATEMENT.

It has been proposed to require the electrification of the steam railway terminals of Chicago as a means of smoke abatement. The results, to which reference has already been made, supply a basis from which to estimate the effects which would be produced by such a change. The proposal brings into prominence three important factors which enter into such a problem. They are as follows:

1. The smoke discharges from the steam locomotive constitute a definite source of atmospheric pollution. The fundamental factor is that of determining the percentage of the total smoke of Chicago which is contributed by the steam locomotive.

2. The electric operation of Chicago's railroad terminals must depend upon the existence and operation of steam-driven electric generating stations. Such sta-

tions must burn coal, and this will give rise to smoke. The complete elimination of the steam locomotive, therefore, while serving to free the atmosphere of Chicago from all locomotive smoke, must lead to the introduction of new sources of smoke in the form of power stations. The benefits in smoke abatement lie in the difference between the amount of smoke made by steam locomotives and that which will be made by the electric power stations.

3. Smoke is not the only polluting constituent of Chicago's atmosphere. Since atmospheric dirt arises from other sources, a given reduction in the amount of smoke will not produce an equal reduction in the amount of atmospheric dirt. If all the smoke of Chicago were eliminated, there would still be dirt in Chicago's atmosphere.

With this understanding of the general problem, it will be of interest to note that the facts which were developed by the Chicago committee permitted a quantitative measure of the several effects considered to be set forth. It is not claimed that these are directly applicable to the conditions of other cities, but they are not without significance in such a relation. The committee's conclusions as to the benefits to be secured through electrification may be summarized as follows:

1. The amount of visible smoke discharged into the atmosphere of Chicago will be reduced by not more than 20 per cent.

2. The amount of solid constituents of smoke (soot, ash, and fuel particles) discharged into the atmosphere of Chicago will be reduced by not more than 5 per cent.

3. The amount of dust and dirt arising from all sources in the atmosphere of Chicago will be reduced by not more than 4 per cent.

4. The volume of gaseous products of combustion discharged into the atmosphere of Chicago will be reduced by not more than 5 per cent.

It is upon the basis of these facts that the merit of any proposal involving complete electrification as a means in smoke abatement must be considered. In the further consideration of this matter the Chicago committee has discussed at length such

questions as the technical feasibility of electrification, the cost and the financial practicability of such a change, with conclusions which need not be herein set forth.

Obviously the electrification of railway terminals can serve to reduce or to eliminate the smoke from a single fuel-consuming service. The reduction of smoke from other services, especially from boiler plants, manufacturing industries, and domestic fires, is a matter of first importance. Various means, such as the more extensive use of gas fuel, smoke washing, and the precipitation of smoke by electrical means, now have limited use and are being suggested for wider application. The detailed discussion of these aspects of the general problem does not come within the province of this paper.

XII. SIGNIFICANT FACTORS IN THE PROBLEM OF SMOKE ABATEMENT.

The work of the Chicago committee shows clearly certain facts which will not fail to interest other communities.

Among the factors in the problem, the significance of which has not commonly been recognized, are six which are worthy of especial emphasis in this connection. The first concerns the number and diverse character of the sources of smoke. It can not longer be urged that this or that particular interest produces the smoke of Chicago; all interests contribute to it. The business man can no longer attach blame to the apartment-house owner, nor the apartment-house owner to the railroad, nor the railroad to the manufacturer, for all are joint contributors to the sum-total of Chicago's smoke. As joint contributors they are jointly responsible for the resulting atmospheric pollution. The problem of smoke abatement, as disclosed by the investigations of the committee, can not be effectually dealt with by giving attention to a single segregated interest; it is one in which every interest must be given attention. It is the problem of the whole city.

A second significant fact disclosed by the researches of the committee is that which emphasizes the relatively great importance of the solid constituents of smoke. Hitherto most discussions concerning smoke, and practically all measures designed to show the extent of atmospheric pollution resulting from it, have dealt only with its cloud effects. It now appears that the cloud effects produced by smoke are of secondary importance as com-

pared with effects produced by the soot and dust of smoke. The problem of smoke abatement, therefore, as viewed in the light of the committee's disclosure, is not entirely or largely a problem of suppressing visible smoke, but is one of suppressing the shower of dust and cinders constantly falling from a smoke-polluted atmosphere.

The third important fact disclosed by the committee's researches is to the effect that atmospheric pollution is not entirely the result of soot and dust in their initial descent to the exposed surfaces of the city, but that such material is subject to secondary flights which persist until some exceptional cleansing process eventually eliminates them. Moreover, the sum-total of atmospheric dirt includes, with the solids of combustion, considerable amounts of dust arising from many activities incident to the life of the city. The problem, therefore, of reducing to a minimum the sum-total of atmospheric dirt is not entirely a problem in smoke abatement, but, to a considerable extent, a problem concerning municipal cleanliness; it must deal with the solid constituents of smoke and with every source from which these arise; it must also deal with all accumulations of dirt in a manner which will promote the cleanliness of the city.

The fourth significant fact is to be found in the obvious tendency of all sources of atmospheric pollution to increase. The fuel-consuming industries of the city are expanding; the traffic of the city streets is increasing, and the amount of merchandise handled in and out of the city is growing year by year. Improvements in the methods of burning fuel or of city cleaning imply an improvement in atmospheric conditions only in a relative sense. The elimination of an entire fuel-consuming service would reduce the amount of pollution entering the atmosphere at the time of its accomplishment, but would constitute no guarantee that the sum-total of atmospheric pollution might not increase subsequently to even greater amounts. Improvement in service may, therefore, result only in checking an undesirable growth. This fact emphasizes the importance of giving attention to every means which can be relied upon to reduce the production of polluting agencies at their source.

The fifth fact to be emphasized is to the effect that a revolution in practice which will result in the elimination of existing sources of atmospheric pollution is not to be expected: first, be-

cause present-day knowledge is insufficient to supply the necessary means; and, second, because the immediate application to all sources of pollution, even of such means as are now available, is mechanically and financially impracticable. However urgent the need, progress in satisfying it must be gradual; it must be evolutionary. Chicago is not peculiar among the cities of the world in the possession of this problem. Every great centre of population is confronted with it. Its intrusion is part of the price which is paid for the privilege of maintaining the activities and the concentration of population which characterize the modern city.

Wherever fuel is burned certain effects appear. These may take the form of visible smoke or of tar or dust emissions, and they must always appear in the form of gaseous products of combustion. As a consequence, objections to smoke are valid only in so far as they may be based upon conditions which are avoidable, and ill-advised restrictions against the use of fuel are not only unreasonable, but harmful to the larger and better interests of the community. It is for this reason that the problem of smoke abatement can not be solved by any simple campaign for the enforcement of restrictions. It is a question which, in all its aspects, is of the highest importance to the welfare of the city. It is a scientific question. It can not safely be answered until many local conditions have been studied and defined. It is a living question, since it assumes new aspects as the state of the art develops.

Finally, it should be obvious that the detailed development of this problem by any city must concern itself with all of the different manifestations of smoke as presented by every different service. This is the sixth significant fact. The real problem in smoke abatement is, in fact, not one of legislation or of inspection, but one of bringing together an enlarged fabric of facts concerning possibilities in the proper utilization of fuel by which legislation and inspection may be safely guided.

That this need may be met in Chicago, the Committee of Investigation has recommended the appointment of a permanent Pure Air Commission which shall be supported by liberal appropriations, which shall be active in the development of scientific research, and which shall have authority in many matters touching the industrial, commercial, and municipal activities of the city.

THE TURPENTINE INDUSTRY IN THE SOUTHERN STATES.*

BY

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A RAILWAY trip through the coastal plain of the South Atlantic and Gulf States, from North Carolina to Texas, shows on every side fallen and charred remnants of trees, stumps innumerable, and occasional huge piles of sawdust. It is a desolate scene in those sections where agriculture has not yet been developed. It represents the destructive path of the naval-stores industry, followed more or less closely by that of lumbering, through that rich, natural heritage of long-leaf pine forests which originally covered completely this entire portion of the country.

From these forests the world has received its chief supply of spirits of turpentine and rosin, averaging in value in recent years some forty or fifty million dollars annually. Yet in the production of this great crop only a very few have received for their toil more than a bare livelihood. The great mass of the turpentine operators have toiled throughout the years in rugged earnestness, in robust health from the out-of-door life in the pine forests,—but always on the outer edge of developing civilization, with few of the comforts and conveniences of life, indifferent to the utter lack of efficient business methods in their operations, and strongly wedded to woods practices which have been handed down from generation to generation as they steadily moved from North Carolina toward Texas.

If the traveller, however, should leave the main lines of travel in Florida or the more westerly states, and by tram or team reach some of the more remote sections, he would find beautiful virgin forests of this same long-leaf pine, the rich brown trunks of

* Presented at a joint meeting of the Section of Physics and Chemistry of the Institute and the Philadelphia Section, American Chemical Society, held Thursday, November 4, 1915.

the trees, free from low-lying limbs, bearing aloft rich crowns of green, and firmly rooted below in a soft carpet of the same hue, formed by the "wire grass" which abounds throughout this territory.

Will the operator, in the exploitation of these remaining forests, profit by the demonstrated inefficiency of past methods? Can he change his attitude of thought toward the living tree on which his operations are based? Is he willing to place himself in line with all other lines of modern industrial life, which have realized, or are beginning to realize, that true progress in any industry must be based, not upon individual opinion or hereditary teachings, but upon scientific research and constant striving for greater efficiency?

Upon the answer to these questions depends largely the future of the naval-stores industry. This is not a matter for indefinite proceeding along inefficient lines: the actual life of the industry is threatened, for the once-considered inexhaustible forests are rapidly disappearing. At the present rate of destruction the end can be fairly well forecasted, especially since no effort is being made toward reforestation.

It was natural that destructive methods should have characterized this industry, for the early settlers in eastern North Carolina found forests of long-leaf pine everywhere. Clearance was necessary for agriculture, crops had to be grown, lumber was needed for industry, homes had to be built, and so the work of destruction began.

It was immediately recognized that this tree, when wounded, is a prolific producer of an oleoresin, "crude turpentine." Furthermore, the rich resinous wood, when heated out of contact with air by piling in heaps and covering with earth, gave off a rich distillate of tar, which could be boiled down to a pitch. These products, tar and pitch, were much needed for the wooden ships with their extensive rigging, at that time universally in use; and so along with agriculture, with its yearly crops, there developed the naval-stores industry with its constant output of immediately marketable products.

The method of conducting the industry called for no plant other than the forests, and so when the yield of the trees began to decrease after two years of operation, new tracts were opened, and the industry began its march southward, from North Carolina

into South Carolina, thence into Georgia and Florida, and then rapidly expanding into the Gulf States, though on a smaller scale.

In the early days in North Carolina no effort was made to separate the crude turpentine by distillation into its constituents, spirits of turpentine and rosin, the gum being shipped to Northern cities or to England for such manufacture. In the early part of the past century, however, this manufacture was trans-

Timber blown down. Results of severe boxing followed by fire.

ferred to the woods, iron stills being at first employed, which later were replaced by the more efficient copper stills such as are used to-day for this purpose.

In the woods, however, there was no corresponding advance in methods of operation, with the exception of slight improvement in the tools employed. Thus for more than a hundred years the method of wounding the tree and collecting the gum remained the same throughout the turpentine belt.

The normal routine on all turpentine farms consisted of the following operations:

"*Boxing.*"—In the winter negro laborers, under the direction

of a white woodsman, cut "boxes." The box was an elliptical cavity cut in the base of the tree, usually just above the junction of a prominent root with the trunk of the tree. It served to collect the gum which flowed during the warmer months from the scarified surface above. The tool used in cutting this box was a very long, narrow axe, the negroes developing consummate skill in the use of this "box axe." The standard dimensions of the box were 14 inches width, 7 inches depth, and 3½

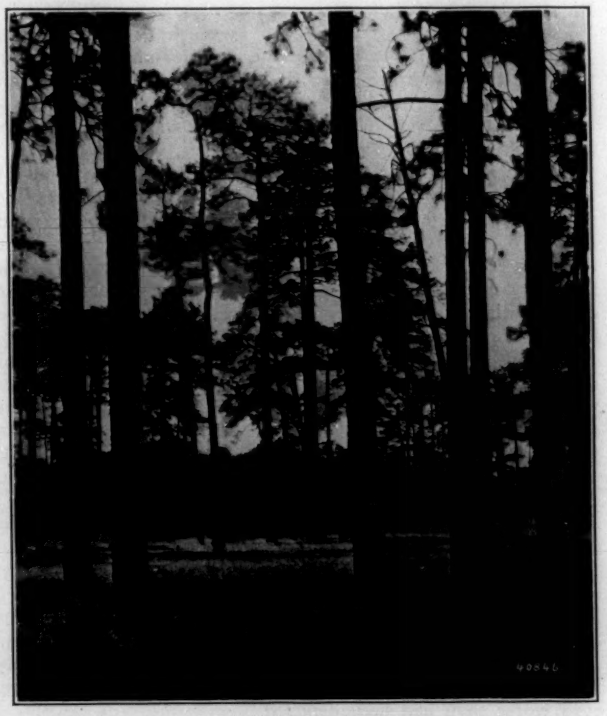
Tree felled by wind. Result of severe boxing on one side.

inches from the outer wood toward the centre of the tree. The number of boxes per tree was increased from one to four, and occasionally five, according to increasing diameter of the trees.

"*Cornering.*"—Box cutting was followed by "cornering." This consisted of removing two triangular chips from immediately above the box by means of the usual wood-chopping axe. The function of cornering was to provide smooth surfaces to direct the flow of the gum into the box.

"*Chipping.*"—As vegetation became active in early spring the work of scarification of the trunk of the tree began, and con-

tinued weekly for eight months. The repetition of this process was necessary, as the flow of gum, greatest during the first three days following the fresh chipping, practically ceased after one



Round or untapped timber. Long-leaf pine.

week. The tool employed in chipping, called a "hack," was a stout U-shaped steel blade attached by a metal shank to one end of a round wooden handle. This handle carried on its other end a heavy iron weight which gave momentum to the free arm

stroke used to draw the blade through the bark and outer sapwood. A slightly modified form of this tool, called the "puller," was mounted on a much larger handle, with no iron weight attached, and was used for the higher reaches of the third and fourth year of scarification.

"*Dipping.*"—At periods of four to five weeks, when, in the judgment of the woodsman, the boxes showed an average filling, the gum was removed into buckets by a broad, flat, spear-shaped tool, called a "dip spoon." Barrels placed at convenient distances in the woods received the gum from the buckets, and were then hauled to the "still" for distillation.

"*Scraping.*"—As the chipping season progressed not all of the gum found its way to the box, for as crystallization of the gum began some of this mass remained sticking to the exposed surface of the tree. At the close of the chipping season this accumulated resinous mass was scraped from the trees, giving thus the name, "scrape," to the product. Its content of spirits of turpentine was much lower than that of the gum from the boxes.

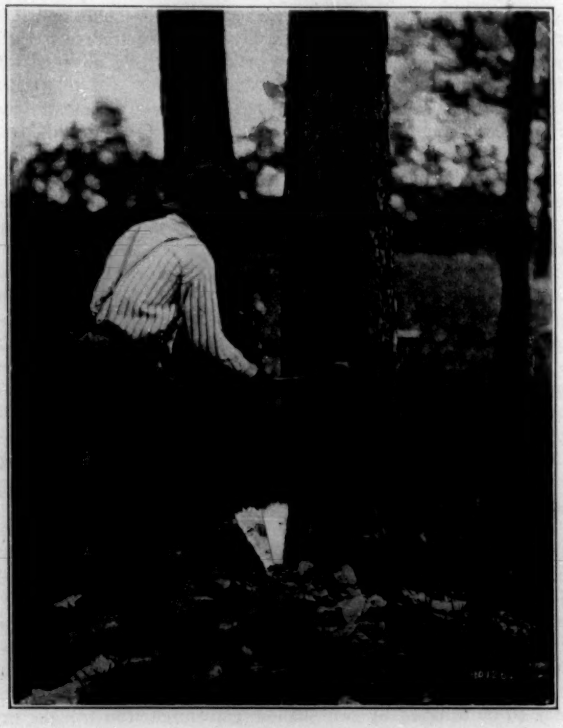
"*Raking.*"—With the completion of the scraping, the final operation was the protection of the trees from the ground fires which prevail throughout the turpentine belt in late winter when the dead wire grass is burned. Such protection, "raking," was effected by means of a common hoe, all combustible material, chips, pine needles, and dead grass, being removed to a distance of about two feet from the base of the tree.

This completed the year's operations in the woods, and the cycle was then renewed from year to year.

The severe strictures on the wastefulness of the industry spoken by the German technologist, Otto N. Witt, led to the determination on the part of the writer to investigate whether or no this criticism was deserved. Correspondence with men familiar with the industry, and a brief visit to a turpentine farm in South Georgia, afforded ample proof that conditions were even worse than had been depicted.

With such waste prevalent, could not something be done to improve the situation? Here the methods of work learned through research in a chemical laboratory asserted themselves. A search of the literature was begun and made as comprehensive as possible. The result of this study and of observations

in the woods made clear the fact that the great evil of this industry, that which more than all else was responsible for the waste and destruction, was the cutting of the "box" in the base



Cutting the "box." Near Ocilla, Ga.

of the tree. This deep cavity, located just where the strain was greatest, caused many of the trees to fall in even slight windstorms. It constituted a great source of danger during fires, especially after turpentine operations had ceased and the tree

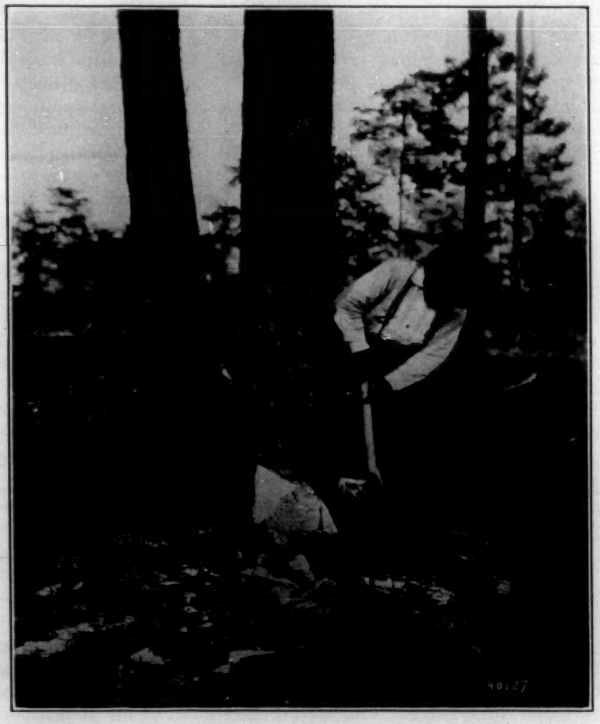
no longer was protected by the annual "raking." The decreased vitality of the tree, due to the severe wound, led in many cases to easy attack by injurious insects. Such evils were easily noticeable, but others, less readily seen, were found upon closer study. With a receptacle at a fixed point, while the distance between the receptacle and the freshly-chipped surface increased regularly from week to week, opportunity was thus afforded for increasing loss of the volatile oil by evaporation, for coloration of the rosin by absorption of oxygen from the air under the influence of sunlight, and for waste in dripping outside the box. It seemed reasonable, moreover, that this severe wound would so decrease the vitality of the tree as to cripple, at least to some extent, the power of the tree to produce crude turpentine. The "box," therefore, should be the primary point of attack in any effort to conserve these forests.

To overcome the evils of the "box," a substitute receptacle must be provided which should inflict but a slight wound in placement on the tree; should be capable of removal at convenient intervals to a point just below the chipping surface; should be extremely simple in its construction, in view of the gummy character of the product it was to receive; easy of operation, because of the unskilled labor which would use it; and cheap, if hopes were to be entertained of its commercial introduction by those who were abundantly satisfied with existing methods and fully convinced that no better could be found—an unfortunate state of mind in these days of progress.

The literature of the French system of turpentining was then studied, and the records of the Patent Office were thoroughly searched. Nothing, however, was found quite free from objections to its ability to meet the above requirements, especially as applied to the system of chipping as practised in the Southern States. In the light gained from this study, however, a substitute was devised, consisting of a simple cup suspended, through a hole near its rim, on a common nail. Into this cup the gum was to be directed by two shallow galvanized iron troughs or gutters, to be inserted about one-quarter inch deep by one of their long edges in correspondingly shallow inclined cuts across the scarified surface of the tree.

With this apparatus provided, and again following the procedure of laboratory research, preliminary experiments were

begun, during the summer vacation of 1901, in the forests of southeast Georgia, near the town of Statesboro, on timber provided, after much persuasion, by some of the leaders of the in-



Cornering the box.

dustry in Savannah, Georgia, who viewed their concessions with an eye of infinite skepticism.

The results of these preliminary experiments were the thorough demonstration of the efficiency of the apparatus, a deeper

grasp of the problem to be solved, a genuine sympathetic interest with the personalities of many employed in the industry, and much knowledge of the habits of the pine. It was completely demonstrated that the dark color of rosin produced under the box system, after the first year of operation, was not at all due to physiological changes in the pine, but solely to the method of collecting the gum. Under this system opportunity was offered for increased oxidation and for absorption of the deeply-colored gum coating the exposed surface, formed by the chipping of previous years. This latter point was important, as the commercial value of the rosin decreases as the depth of color increases.

The United States Bureau of Forestry, hearing of the proposed preliminary experiments, tendered the writer a collaboratorship in order to secure publication of the results. The experiments were so full of promise that it was agreed that the work should be promptly resumed at the opening of the next season, with field experiments on a commercial scale, under the auspices of the Bureau of Forestry. Accordingly the experiments were begun in February, 1902, on the turpentine farm of Powell, Bullard & Company, a well-known firm operating in southeast Georgia, near the town of Ocilla.

For these experiments the following policy was adopted at the outset:

First, the timber was to be provided by the firm; the cups and gutters and cost of installation, by the Bureau.

Second, the labor was to be none other than such as was employed in the regular work of the farm.

Third, the experiments were to be restricted solely to the "box" question and the practicability of the substitute cup and gutters. Therefore the work of chipping, dipping, and scraping should be conducted in the normal way.

Fourth, four sets of comparative experiments were to be conducted simultaneously, one on virgin timber, and three on boxed timber which had already been operated respectively one, two, and three years. This would determine, so far as possible in one year, the influence of the box on the timber and on the income of the operator.

Fifth, the results should be taken from the records of the company, whose statements would be readily accepted by all other operators.

So far, so good. Then troubles began. The manufacturer, delayed in his work, did not deliver the equipment until the chipping season was nearly at hand. This led to shortcomings, un-

Chipping the first "streak" above the virgin box.

dreamed of at the time, and which in after-years caused the loss of many thousands of dollars; but this will be discussed later. Next, labor troubles were unexpectedly encountered. The negro laborer proved even more conservative than the white operator

and woodsman, and assumed the remarkable attitude that the "flower-pot" method of making turpentine was more properly the work of women and children, and not suited to the dignity of full-grown men. This may be difficult of belief, and it was strange in the light of later developments, but it proved a serious obstacle for some time. By dint of patience, tact, and kindly reasoning this trouble was at last overcome sufficiently to enable a beginning of work in the woods with three laborers, but up to the very moment of actual handling of the axe the chagrin and mortification of those three negroes, too inefficient for the regular box-cutting squad, were comical, though the situation had its serious side in that the whole question of the carrying out of the experiments was at stake in the successful solution of this labor difficulty. It is sufficient here to state that in a short while the problem was completely solved, and as success in the experiments became more and more marked the comical picture then became the rather haughty air and proud demeanor of those who gleefully dubbed themselves "cup niggers!"

To return to the experiments: three crops were selected, consisting each of 10,000 boxes, the unit of operation. These three had already been under operation one, two, and three years respectively. On one half of each of these crops cups and gutters were installed near the point where the chipping would begin. On the other half the gum was collected in the normal way, in the box, at the base of the tree. These experiments would determine the practicability of the equipment at varying heights on the tree; the quality, as to color, of the rosin produced from gum collected under the two systems; and would give some information as to relative waste from evaporation, etc.

The main interest, however, centred in the experiment on virgin timber, where the two systems could be put into operation under fully equal conditions. For this experiment a tract of timber of fair average quality was selected by the firm just outside of the town. To insure accuracy of the experiment, this timber was carefully and repeatedly cruised by experienced woodsmen, and a division made as to location of cups and boxes respectively. In this division it was decided to alternate the "drifts" (subdivisions of a crop) of cups and of boxes. This also furnished more uniform weather conditions in working the two halves. The entire crop was to be chipped by one man, and the

dipping was to proceed every three weeks simultaneously in the cupped and boxed halves of the crop, the gum to be collected in different sets of barrels. The presence of varying amounts of

Gutters and cup in position.

trash and water would render inaccurate the results from measuring or weighing the gum. Therefore it was distilled and record kept of the number of gallons of spirits of turpentine obtained from each lot, and separate sales made of the rosin produced.

No difference in quality of rosin was expected or found here. As the distance of flow of the gum was the same in each set, loss of spirits of turpentine by evaporation was equalized. All precautions were taken so that whatever difference of results might be found in the yields from the two halves could be as-

Unboxed tree with cup and gutter in position at end of first year's chipping, showing correct position. Ocilla, Ga.

cribed to no other factor than the influence of the severe wound caused by box cutting on the productive power of the trees. The advancement of the idea that it decreased productive capacity had met with hoots and jeers on all sides; and here in this crop, it was felt and stated without the least effort of repression, would be demonstrated the superiority of the judgment of the "practical" man over the theoretical college professor.

The work of installation began. Two flat faces meeting in a central line were cut with common axes to adapt the round tree to the straight-edged gutters, two laborers with broadaxes made across these plane surfaces the incisions for the gutters, which were promptly inserted by another group of laborers, the upper gutter reaching just to the centre of the face and emptying into the opposite gutter equally inclined, running about one inch lower and extending about two inches beyond the angular centre of the face, to provide a suitable hanging of the cup into which all of the gum dripped. While awaiting the arrival of the cups and gutters, the box-cutting squad and the "cornerers" had been gleefully at work in the other half of the crop.

With the respective receptacles provided and installed, the work of chipping began—and the race was on. The detailed results are given in Table 1.[1]

TABLE 1.

First-year Crop—Dippings.

Number of dipping	Date of dipping		Number of chippings	Barrels of dip obtained		Spirits of turpentine on distillation (gallons)		Excess spirits of turpentine (gallons)	
				Boxes	Cups	Boxes	Cups	Boxes	Cups
1.....	April	14	3	*9¾	†7¾	101.6	84.3	17.3	....
2.....	May	5	3	9¼	10⅞	111.0	130.5	....	19.5
3.....	May	26	3	12	14½	136.8	178.3	....	41.5
4.....	June	16	3	12½	17⅛	143.3	191.2	....	47.9
5.....	July	7	3	12⅛	14⅝	142.4	175.2	....	32.8
6.....	July	28	3	10½	12¾	115.2	141.7	....	26.5
7.....	August	18	3	10	11⅜	106.6	126.6	....	20.0
8.....	September	8	3	8	10¼	86.1	105.9	....	19.8
9.....	September	29	3	7⅝	9½	80.8	106.0	....	25.2
10.....	November	4	5	‡10¼	12⅞	110.9	145.6	....	34.7
Total...	.....		32	101⅞	121⅝	1,134.7	1,385.3	17.3	267.9

* Including resin from box cutting and cornering.
† Including resin from placing cups on trees.
‡ Boxes dipped after trees have been scraped.

The unexpected shortage from the cups on the first dipping led to great rejoicing among the box supporters, and to undoubted apprehension on the part of the solitary backer of the cups. The second dipping, however, altered the situation, and by the last of June the victory for the cups was so complete that all were

[1] The tables throughout this paper are from Bulletins 40 and 90 and Circular 34 of the United States Forest Service.

converted. The beginning of the end of the box system had been reached. From this point on all went well. Labor was anxious to enlist, enthusiasm had supplanted scoffing, and now the chief effort of the original cup backer was to guard against possible inflated results, due to some over-zealous convert, which results might not be justified by the facts in the case, for in spite of convictions formed in advance of experiment it was, as in all research, the truth which was sought.

Several years passed, much thought was expended, and many experiments were made before the true interpretation of that shortage on the first dipping was obtained and its remedy provided. This will be discussed later.

Meanwhile the distillation of the gum from the second-, third-, and fourth-year crops showed uniformly high-grade rosin from the cups, as contrasted with the low-grade rosin from the corresponding boxes, and the equipment proved itself readily adaptable to the increasing heights of chipping.

The results of net rosin sales from all four crops are given in Table 2.

TABLE 2.

Season's Record of Net Rosin Sales.

Half crop	From dip	From scrape	Total	Excess net sales	Per cent. excess net sales, cupped trees
First year:					
Cups	$401.72	$47.72	$449.44	$85.51	23.50
Boxes	328.40	35.53	363.93	.....	.....
Second year:					
Cups	266.34	49.25	315.59	144.13	84.64
Boxes	104.51	66.95	171.46	.....	.....
Third year:					
Cups	171.27	27.44	198.71	132.65	200.80
Boxes	39.49	26.57	66.06	.....	.....
Fourth year:					
Cups	167.33	29.23	196.56	132.56	207.13
Boxes	36.09	27.91	64.00	.....	.....

The experiments with the second-, third-, and fourth-year crops were discontinued at the end of the year, having served their purpose. The working of the virgin crop, however, was continued two years longer. The complete results for the three years' operation of this crop are given in Tables 3, 4, and 5.

TABLE 3.

Spirits of Turpentine from Half Crops.

Year	Cups			Boxes			Excess from cupped half crop	Net price per gallon at time of operation	Value of cup excess
	From dip	From scrape	Total	From dip	From scrape	Total			
	Gallons	*Gallons*	*Gallons*	*Gallons*	*Gallons*	*Gallons*	*Gallons*	*Cents*	
First.....	1,385.3	205.0	1,590.3	1,134.7	153.7	1,288.4	301.9	40	$120.76
Second....	1,103.5	165.0	1,268.5	705.2	226.6	931.8	336.7	45	151.52
Third.....	781.3	136.0	917.3	536.1	190.5	726.6	190.7	45	85.82
Total...	3,270.1	506.0	3,776.1	2,376.0	570.8	2,946.8	829.3	..	358.10

TABLE 4.

Net Sales of Rosin from Half Crops.

Year	Cups			Boxes			Excess from cupped half crop
	From dip	From scrape	Total	From dip	From scrape	Total	
First.....	$401.72	$47.72	$449.44	$328.40	$35.53	$363.93	$85.51
Second.....	286.88	58.24	345.12	132.42	84.08	216.50	128.62
Third.....	212.60	61.65	274.25	124.76	79.70	204.46	69.79
Total.....	901.20	167.61	1,068.81	585.58	199.31	784.89	283.92

TABLE 5.

Summary of Gain from Cupped Half Crops.

Years	Spirits of turpentine	Rosin	Total
First.....	$120.76	$85.51	$206.27
Second.....	151.52	128.62	280.14
Third.....	85.82	69.79	155.61
Total.....	358.10	283.92	642.02

Total Value of Products from Three Years of Operation.

Cupped half crop..... $2,688.55
Boxed half crop..... 2,046.53

Gain from cupped half crop..... 642.02 = $1,284.04 per crop.

That the distribution of the timber in this virgin crop had been well equalized was shown by measurements of diameters of all trees in the crop and by a determination of the average number of cups or boxes per tree throughout the crop.

As the work progressed, careful record of the dead and down trees were made in each half. The count at the end of the three-year period is shown in Table 6.

TABLE 6.

Record of Down and of Dead Trees.

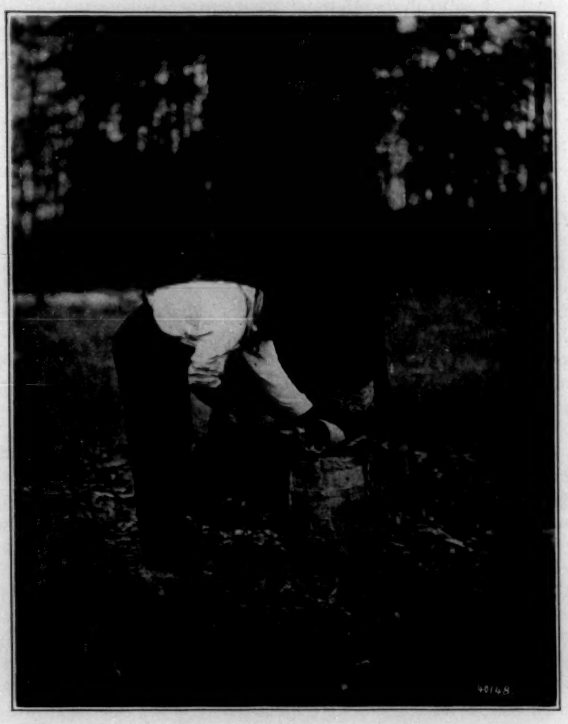
	Number of trees blown down		Number of trees dead	
	Boxed	Cupped	Boxed	Cupped
In 1 year.....	8	3	35	16
In 2 years.....	60	34	139	83
In 3 years.....	78	44	217	150

During the chipping season portions of some of the chipped surfaces became unproductive, locally termed "dry face." The results of the measurement of the extent of "dry face" in the two halves of the crop showed an excessive amount in the boxed half at the end of the first year. From that time on the amounts, while increasing in each, showed less striking difference. Evidently the cause of increased "dry face" in the last two years lay more and more in the chipping, and this observation led to later valuable experiments on comparative yields from lighter chipping.

The results of the first year's experiments were communicated to the turpentine operators at their annual convention. Much interest was aroused and some enthusiasm. The next few months, however, proved an interesting testimonial to the "follow-up" policy of the wise advertiser, for, in the three-month period spent in arranging for the manufacture of the equipment at a reasonable cost and in the preparation of an account of the experiments for publication as a government bulletin, interest in the matter completely disappeared. It was only through the most persistent efforts that interest was sufficiently re-aroused, in those at one time enthusiastic, to assure the commercial utilization of the rather limited output of the cup factory.

This first season's use of cups by the operators assured the future, the results obtained more than confirming the experimental results of the previous year. Instantly the demand increased; prejudice slowly gave way; the quality of the cups was improved with increasing experience at the factory; timber

owners made concessions on price of leases, provided cups instead of boxes, eventually stipulating that timber could not be worked if box cutting was the intention; and labor throughout



"Dipping" the cup.

the territory became familiar with and enthusiastic about the new method. Thus was the box system, with its attendant losses, replaced by the more efficient cup system. To-day box cutting is practically a thing of the past, while many forms of cups, to

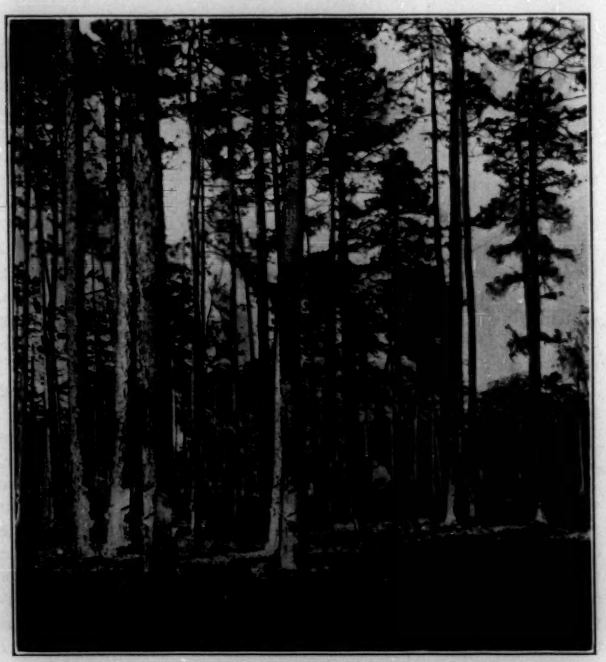
suit individual requirements, have become every-day articles of commerce.

From the outset, railway officials of the Southern States, keenly alive to the welfare of the territory tributary to their lines, were strongly sympathetic with this movement, and by their prompt and intelligent handling of the question of freight rates on the equipment facilitated greatly the universal introduction of the new method.

To encourage the adoption of the new system, the Forest Service adopted the wise policy of offering, free of cost to the operators, the services of the writer in inaugurating the work on a turpentine farm. Never to be forgotten was the first experience in this work of instruction, when on a cold, drizzly February day, at a South Georgia saw-mill, there was handed over for instruction a group of sixteen young negro convicts, in characteristic garb and utterly devoid of any knowledge of turpentine operations. The situation seemed impossible and hopeless, but the future of the work was at stake. Fortunately experience gained in years of teaching in the class-room came to aid. The setting was entirely changed, but the methods of pedagogy were applicable and necessary. The effort succeeded. After such an experience all others were easy.

The "practical man," however, had his inning, for a little later, working in timber near the Gulf Coast of Florida, it was found that such timber was so tough that it was impossible to make smooth, flat faces on the tree for the gutters with the ordinary axe employed. After a long day of struggle, with defeat clearly ahead, the turpentine operator suggested the use of the broadaxe for this purpose. The experiment was tried and immediately succeeded. Later another step forward was taken by the suggestion of another operator that in hewing with the broadaxe the bevelled side of the edge be placed next to the tree. This was revolutionary from an axeman's point of view, but it was tried and its advantages were immediately noted, for there was no difficulty in forcing the axe to the surface at the base of the cut, thus saving the tree much useless wounding and so increasing the speed of operations that in a little while it was possible, with an equal force of laborers, to install three crops of cups while one crop of boxes was being cut. Such details may appear trivial, yet each had its influence on the rapid introduction of the system.

As reports began to arrive concerning commercial experiences with the system all agreed on increased yield, but all agreed likewise on the unusually large number of chippings required to fill the cups with gum at the beginning of the season, especially



Third-year boxed timber with cup system.

when compared with boxes on similar timber near the cupped trees, the capacity of cup and box being the same. After this first dipping the superiority of the cup system readily showed itself in largely-increased yields. Here was a recurrence of the mortifying experience with the first dipping of the virgin

crop in the experiment at Ocilla. What could be its explanation? How could the trouble be overcome? Various suggestions were made and numerous experiments tried by men of all types in all sections, but without success in overcoming this chief defect in the system.

A few years later the writer had opportunity to visit Professor A. Tschirch in his laboratory at Berne, Switzerland, and there learned his views concerning resin flow, views based on the results of experiments on many pines in the neighborhood. According to Tschirch the resin ducts, found scattered throughout the wood of a normal pine, contain a resin which is formed as a result of natural life processes in the living tree. Such a product is, therefore, a purely physiological product, and such ducts he designated "primary resin ducts." These yield only a small quantity of crude turpentine when the tree is wounded. Immediately after the wounding, however, there begins in the outer fresh wood the formation of a very large number of resin ducts, both above and below the wound, forming an anastomotic system, which pour out crude turpentine in great quantity as a healing balsam over the wound. Such an exudate is a pathological product, and the ducts producing it he termed "secondary resin ducts." These extend four to five inches above the wound, requiring four to five weeks for their full development.

In the light of this knowledge the explanation of the excess yield of the boxes over the cups on the first dipping was simple. When the boxes were cornered a full-width, V-shaped surface was formed above which the secondary resin ducts formed in abundance during the several weeks which elapsed before the chipping season began. Then when the first chipping was made the cut traversed secondary resin ducts along its full length and a maximum yield was obtained. On the other hand, the late arrival of the cups for the experimental work made it necessary to begin chipping immediately afterward. The secondary resin ducts had not fully formed during this brief interval, and there was a correspondingly low yield of crude turpentine, which, however, rapidly increased later as the ducts increased. Again, in explanation of the same difficulty experienced by operators who placed their cups on the trees many weeks in advance of the chipping season, it must be remembered that the flat faces for the gutters were then being made on the tree by the broadaxe. The cutting

of a straight-edged tool into a round tree exposed the fresh wood above in the form of two curved lines, meeting at the centre of the cut surface. Again, the secondary resin ducts formed, but

Removing "scrape" (hard resin) at end of second-year box.

following the outline of the cut. When, therefore, these trees were chipped only about half of these ducts, those near the centre, were traversed by the downwardly-inclined stroke of the hack. Hence a flow of gum far below that in the box system, but again

rapidly increasing after the first full-width cut formed by the first chipping. This suggested a simple method for overcoming the losses encountered during the first six or eight weeks of operating under the cup system; namely, the placing of the gutters on the trees in winter should be followed immediately by one full-width chipping and the trees allowed to stand, without further chipping, four or five weeks. Opportunity would thus be given for full formation of the secondary resin ducts along the full width of the chipping surface, as in the box system.

These views were laid before a number of operators using the cup system, and they were requested to try the modified method on some of their timber during the next winter. They agreed: the experiments were carried out, and in every case the cure for the evil was found to be complete, cups so placed yielding a greater amount on the first dipping than boxes or than cups placed without the one winter chipping. Conservative estimates made by experienced operators place the total annual gain from this slight modification of woods practice at not less than $500,000. Could there be asked a better illustration of the value of pure university research, as was that of Tschirch, for efficient industrial operation?

With the future of the cup system assured, attention was next turned to the relative yield of crude turpentine with reduced wounding of the tree in chipping. These experiments were conducted near Green Cove Springs, Florida.

In order to interpret the results clearly, all trees were cupped, and one of the crops chipped to normal depth, seven-tenths of an inch into the new wood, the thickness of the chip being such as to carry the chipping up the trunk at the normal rate. This crop was designated A.

In another crop, designated B, the depth of the chipping was reduced from seven-tenths to four-tenths of an inch, all other conditions being identical with the standard crop, A.

In a third crop, designated C, the thickness of the chip was so reduced that the same elevation on the trunk would be reached in four years as was reached in three years in crop A, all other conditions being alike in the two crops.

Finally, in a fourth crop, designated D, no tree under ten inches was worked; the minimum diameter for trees bearing two cups was raised from twelve inches, as in crop A, to sixteen

inches; and, finally, no tree bore more than two cups, regardless of its larger diameter. In this crop the chipping was the same as in the standard crop, A.

The results of the four years of work on these crops are given in Table 7.

TABLE 7.

Crop	Dip		Scrape		
	Yield	Increase	Yield	Increase	Decrease
	Pounds	*Per cent.*	*Pounds*	*Per cent.*	*Per cent.*
A	206,235	.....	47,742	.....	.....
B	211,911	2.75	44,838	.....	6.08
C	214,503	4.01	39,775	.....	16.69
D	279,260	35.41	53,915	12.93	.....

The marked success of these experiments led to a further experiment for one year, in which was compared with a standard crop, such as A above, the yield from two crops, designated G and H, in which both modifications of chipping, shallow and thinner cuts, as in B and C above, were combined. The results are given in Table 8.

TABLE 8.

Crop	Number of cups	Number of chippings	Yield of dip	Increase
			Pounds	*Per cent.*
Walkill Turpentine Company	9,880	35	90,094	..
G	9,880	35	124,292	38
H	9,880	35	121,474	35

Thus was the way clearly pointed out for more conservative treatment of the trees, the result being largely-increased yields.

Are further experiments on the reduction of the wound in chipping justified? This is a difficult question to attempt to answer. Certainly there is a limit to which such reductions can be carried, beyond which financial loss will result, under existing conditions of cost of stumpage and wages of labor. If the tree is not wounded, crude turpentine is not produced; if it is girdled, the tree dies. Somewhere between these extremes lies the most efficient operation. From the results already mentioned it is evident that past practice in chipping has been on the side of too

excessive wounding. Whether or no the limit should be further reduced can be determined only by experiment.

One abuse, however, has arisen in connection with the spread of the cup system; namely, the general practice of cupping very small trees. Such trees were not brought into operation under the box system, as they were too small to receive a box, but they could be cupped with ease. Two strong objections hold against this practice. *First*, the trees of the future naval-stores industry are being destroyed, a well-marked case of child-labor abuse for which there is no legislative correction. *Second*, the judgments of the leaders of the industry agree that the operation of such small trees is unremunerative in itself, yet often producing sufficient crude turpentine to seriously depreciate the market value of that produced from the larger trees. Much has been spoken and written by these leaders against the practice, but still it continues. Is not experiment advisable here? The following is suggested, and it is hoped that the suggestion will receive the consideration of the United States Forest Service. An investigation is needed of what is the actual yield from a crop of ten thousand of these very small trees during a period of three or, better, four years of operation. Such an investigation would give facts where now mere opinion prevails. The experiment would not be costly, because it could be carried out in connection with the regular operations of a turpentine farm. It would require only efficient supervision; the dipping from the small trees to be kept separate from those of unquestioned size, say ten inches and over in diameter; the yields from the two lots compared, and the results published for the benefit of all. Such a publication would constitute a valuable contribution to the literature of this subject, and such facts would carry far more weight than any amount of spoken or published criticism.

Leaving now questions connected with woods-practice, let us follow the barrels of gum to the distillery, or "still," as it is uniformly called. This manufacturing plant is exceedingly simple, and, as a rule, roughly built, the rapidly-shifting character of the industry not justifying more pretentious housing. A large copper kettle, the "still" proper, is set in brick masonry above a fire-box in which pine wood is burned. Eight to ten barrels of the gum, mixed with chips, dirt, and some water, constitute a charge, the distillation of which requires from three to four hours. The

kettle is connected by a removable "still head" to a coiled copper worm, set within a large wooden tank, the condenser, into which cold water flows or is pumped at the bottom, cooling thus the hot mixed vapors of steam and spirits of turpentine in the condenser coil. The heated water is led off by an overflow or is partly used by running along a narrow trough leading from the top of the condenser to a small, funnel-shaped opening in the lower part of the still head, and emptying into the still and on to the boiling gum below, the steam thus generated aiding materially

Hauling crude resin from the turpentine orchard to the still.

the separation of the volatile spirits of turpentine from the non-volatile rosin. The proper regulation of this flow of water has been generally determined by the sound produced by the boiling mass heard at the mouth of the condenser. Recently the use of inset thermometers for the purpose of controlling the distillation has largely increased. The condensed liquids, flowing from the mouth of the worm, separate at once in the receiving vessel into two layers. The lighter spirits of turpentine is pumped into large storage tanks or is dipped into oak barrels, which have been thoroughly coated inside with glue. It is now ready for marketing. When the volatile oil is practically all removed, the still head

is taken off, and the chips are skimmed. In the case of virgin dip this skimming is done as soon as the gum melts and before distillation begins. Finally, when all water has boiled off, a necessary precaution to prevent the rosin being opaque, the molten rosin is allowed to flow from the still through a tail pipe, leading from the bottom of the still, to two strainers placed the one above the other. The upper strainer consists of coarse wire gauze, and retains unskimmed chips. The lower strainer, of fine brass gauze over which are placed layers of cotton batting,

Turpentine still. Ocilla, Ga.

retains the dirt and smaller portions of trash. From these strainers the rosin flows into a long wooden vat, from which it is promptly dipped into barrels, where, upon cooling, it solidifies and is then ready for shipment.

Crude as the method appears to the casual observer, nevertheless careful study of this system as compared with the much more expensive systems in France has convinced the writer that, given a good stiller, equally good results are obtained by this very inexpensive outfit. Of course, the presence of the personal element, as represented by the stiller, is always a risk in manufactur-

ing operations, and it would seem to be a needless risk in the light of its complete elimination in the French system of "mixed injection," where heating is effected partly by free flame and partly by steam; where water vapor is furnished both by inflowing hot water and by direct injection of steam; and where operations are controlled entirely by the thermometer. Such plants are not expensive and are very simple in operation.

The suggestion has recently been made that this industry would be placed on a much more efficient basis if the smaller stills in the woods were done away with, the gum hauled in tank cars direct to a central distillery, advantageously located, and there distilled. This suggestion contains many thoughts which justify the belief that here lies the way to the next decided step forward in the evolution of this industry, if questions connected with transportation can be properly worked out. Undoubtedly there is much waste at the present small distilleries. Important matters concerning utilization of by-products cannot be properly handled under the present system. Much demoralization of labor arises from the still being near the turpentine camp. On the other hand, the handling of crude turpentine in sufficient quantities at a central distillery would justify the presence of the most efficient forms of stills and of labor-saving devices common to all handling of material in large quantities. Of possibly still greater importance is the fact that operations on such a scale would justify the employment of competent chemists, who, in addition to the careful control of the operation of the distillery, could supervise the manufacture of rosin oil directly from the molten rosin, of the various commercial articles into which such products enter, and who could by systematic research find new uses for and new transformations of the various products, thus guiding the industry to wider fields of application, and enabling it to more fully keep abreast of that progress characteristic of all industries which wisely make use of the services of well-trained chemists.

Wind-deflecting Mask for the Use of Locomotive Engineers. ANON. (*Scientific American*, vol. cxiv, No. 3, January 15, 1916.)—A few years ago an engineer on a Canadian railroad was tried for killing several passengers as a result of a rear-end collision between his engine and a passenger train ahead. His defence was simply that the weather was 40° below zero, a 40-mile wind was blowing, the severity of which was greatly increased by the speed of his train, and it was a human impossibility to withstand the cold long enough to get even a glimpse ahead from the open window. The other windows were so incrusted with ice that they might as well have been solid walls, for all that could be seen through them.

The engineer won his case on the strength of his testimony, but as a result of the case a mask was invented which eliminates the discomforts of looking forward in bitter cold weather and gives the engineer a clear and unobstructed vision, without even glass intervening. The result is secured by deflecting the air currents downward as they enter the mask, and by forming a suction or draft at the bottom all air is drawn away from the engineer's face. So perfect are the results secured that a match held at the back of the shield burns steadily. The space between the deflecting partitions at the top and those at the bottom of the mask is open, and it is through this space that the engineer secures a clear view of the track ahead. The device is being generally adopted by the Canadian railroads as a safety measure and for the greater comfort of their enginemen.

Newly-invented Circular Computer of Marked Accuracy. ANON. (*Scientific American*, vol. cxiv, No. 3, January 15, 1916.)—In an endeavor to provide a computer of great accuracy for the use of engineers, Louis Ross, a civil engineer of San Francisco, has devised a new instrument that is at once compact, simple, inexpensive, and, most important of all, has an accuracy equivalent to a slide-rule 100 feet long. The new computer consists essentially of a graduated dial rotating under a slotted cover, a floating guide, and a slide mounted at the right of the slot. The dial carries a scale of numbers reading to five significant figures throughout. The slide carries a miniature of the dial scale reading to three figures. It coöperates with the dial, checks and points out the precise answer and locates the decimal point. For instant or approximate results the slide alone may be used.

The variable graduations of the ordinary slide-rule are replaced by uniform graduations along a spiral curve so proportioned that the angular motion of the index represents the logarithm of the scale reading. The length of the scale, according to the inventor, is 120 times as great as the A and B scales in the ordinary 10-inch slide-rule, although the instrument is only 8 inches in diameter. The new computer is made of metal throughout, and the graduations are engraved on silvered metal surfaces. It is slightly over 8 inches in diameter and weighs less than one pound.

THE THEORY OF SOME VARIABLE NEUTRAL TINT-ABSORBING SCREENS.*

BY

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ONE of the most important and frequently-occurring problems in the design and use of optical and photometrical apparatus is how best to vary the intensity of a light flux easily and at the will of the operator. Many different solutions to this problem have been devised, a list of which need not be given here. It is the purpose of this paper to collect for record some incidental work, extending over the past two years, on some neutral tint-absorbing screens made for this purpose.

The three screens that have been studied are (1) the opaque line grating,[1] (2) the perforated opaque plate, and (3) the parallel wire grating. In the following work a parallel light flux is always assumed.

The first screen was made by ruling two gratings on glass with about 24 black lines per centimetre, then placing the two gratings and the lines parallel and slightly separated.[1] When this screen is rotated about an axis parallel to the lines, the transmission varies at a rate determined by the separation of the surfaces. Part of a section perpendicular to the lines is shown in Fig. 1. The lines are shown staggered and not exactly opposite one another, the angle of staggering being denoted by ϕ as indicated. The angle of rotation is called θ and is taken positive for counter-clockwise rotation, being equal to zero when the surfaces of the screen are normal to the light flux.

For this screen we have, using the symbols of the figure,

$$X = (S - S_1 + S_2) \cos \theta \text{ where} \qquad (1)$$
$$S_1 = T \tan \phi \text{ and}$$
$$S_2 = T \tan \theta$$

(1) becomes

$$X = (S - T \tan \phi + T \tan \theta) \cos \theta \qquad (2)$$

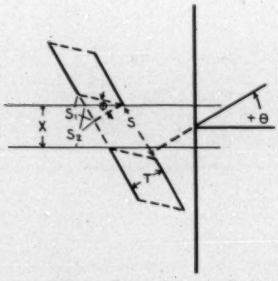
* Communicated by the Author.

We will now express (2) in terms of the maximum transmission as unity. The light flux passing through unit area of the screen when normal to the flux is proportional to the total open area, which equals the number of openings, n, per unit area, times the area of each, X, multiplied by the other dimension, a, thus: open area $= n X a$.

Now at any other angle, θ, to the normal the number of openings exposed to this same flux is $n \sec \theta$ and their open area

$$n X a \sec \theta$$

FIG. 1



Part of a section of the opaque line grating perpendicular to the rulings.

The maximum value of X is $S \cos \theta$, and the maximum area $nSa \cos \theta$ times $\sec \theta$.

The transmission then becomes

$$\frac{n X a \sec \theta}{nSa} = \frac{X \sec \theta}{S}$$

Multiplying (2) by $\frac{\sec \theta}{S}$, we get

$$\text{Transmission} = 1 - \frac{T}{S} \tan \phi + \frac{T}{S} \tan \theta \qquad (3)$$

This holds for all values of θ taking θ + or − on opposite sides of zero. For $\theta > \phi$ after (3) has passed through a maximum (3) changes to

$$\text{Transmission} = 1 + \frac{T}{S} \tan \phi - \frac{T}{S} \tan \theta \qquad (4)$$

There is also a similar pair of equations representing a second case where the screen as shown in Fig. 1 is rotated 180° through a plane perpendicular to the paper, the corresponding equations becoming

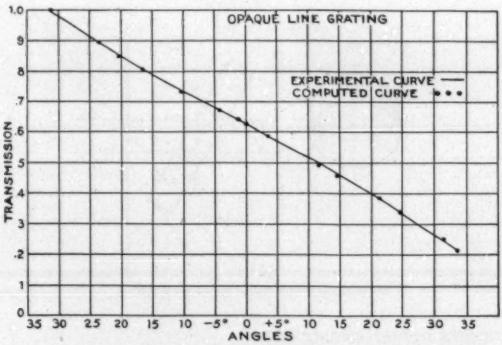
$$\text{Transmission} = 1 - \frac{T}{S}\tan\phi - \frac{T}{S}\tan\theta \qquad (5)$$

and for $\theta > \phi$ through a maximum

$$\text{Transmission} = 1 + \frac{T}{S}\tan\phi + \frac{T}{S}\tan\theta \qquad (6)$$

Fig. 2 shows in the solid line the calibration curve of such a screen when the staggering is of the second case, making (5) ap-

FIG. 2.



An experimental and theoretical calibration curve of the opaque line grating.

plicable. The calibration could not be extended to show the equivalent of (6) also. The equation fitting this curve is

$$\text{Transmission} = 0.623 - 0.620\tan\theta \qquad (7)$$

and the computed points are shown as dots in Fig. 2. (7) in the form of (5) is

$$1 - 0.620\tan 31°\,18' - 0.620\tan\theta \qquad (8)$$

This curve has the desirable characteristic of passing through a point of inflexion which makes it approximately linear through that region.

The second grating studied was a brass plate drilled as closely as possible. Fig. 3 shows a section of one hole and also a perspective view of the same from one side. We have

$$Z_1 + Z = 2R\cos\theta \tag{9}$$

where $Z_1 = T\sin\theta$ and

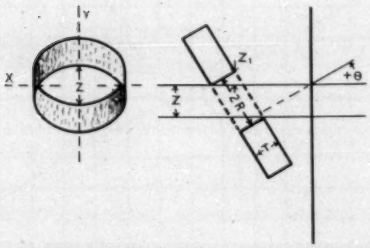
$$Z = 2R\cos\theta - T\sin\theta \tag{10}$$

As the plate is tipped from the normal to the light flux the equation for each apparent ellipse is

$$\frac{X^2}{R^2} + \frac{Y^2}{(R\cos\theta)^2} = 1 \tag{11}$$

$$X = \frac{+}{-}\frac{\sqrt{(R\cos\theta)^2 - Y^2}}{\cos\theta} \tag{12}$$

FIG. 3.



An opening of the drilled metal plate screen.

For area of one opening take

$$A = 4\int X\,dy$$

between the limits of

$$Y = R\cos\theta$$

$$Y = R\cos\theta - \frac{Z}{2} = \frac{T}{2}\sin\theta$$

$$A = \frac{4}{\cos\theta}\int_{\frac{T}{2}\sin\theta}^{R\cos\theta}\sqrt{(R\cos\theta)^2 - Y^2}\,dy \tag{13}$$

$$A = R^2\cos\theta\left[\pi - 2\sin^{-1}\left(\frac{T}{2R}\tan\theta\right)\right] - TR\sin\theta\sqrt{1-\left(\frac{T}{2R}\tan\theta\right)^2} \tag{14}$$

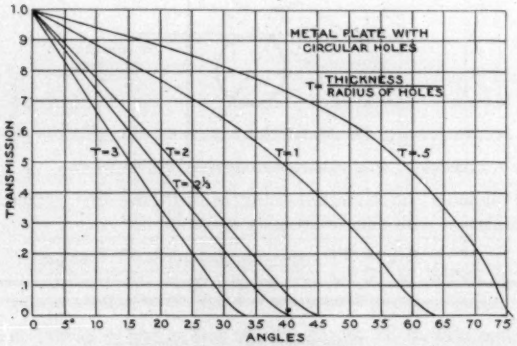
We will consider T as measured in terms of R, which will be taken as unity. The total transmission will be as above, equal to the open area nA, subtending per unit normal area. At $\theta = 0$ this open area is $n\pi R^2$ and at θ, $nA \sec \theta$, therefore for maximum transmission unity we have

$$\frac{nA \sec \theta}{n\pi R^2} = \frac{A \sec \theta}{\pi} \text{ where } R = 1.$$

Multiplying (14) by $\frac{\sec \theta}{\pi}$ it becomes:

$$\text{Transmission} = 1 - \frac{2}{\pi} \sin^{-1}\left(\frac{T}{2}\tan\theta\right) - \frac{T}{\pi}\tan\theta\sqrt{1-\left(\frac{T}{2}\tan\theta\right)^2} \quad (15)$$

FIG. 4.



Theoretical calibration curves for the drilled metal plate for various ratios of thickness to radii of the holes.

Fig. 4 shows five curves plotted according to (15) for $T = 0.5$, 1, 2, $2\frac{1}{3}$, and 3 respectively. They are interesting as showing how the curves pass through practically a straight line for $T = 2\frac{1}{3}$, the only sharp bend being a short one at the lower end.

The third and last screen studied was the parallel wire grating, a part of a section of which is shown in Fig. 5.[2] A rigid metal frame was wound uniformly and tightly with a soft iron wire. The portions of the wires that bend over the edges of the frame were then soldered and all the wire on one side of the frame was then cut away, leaving the other half intact. The

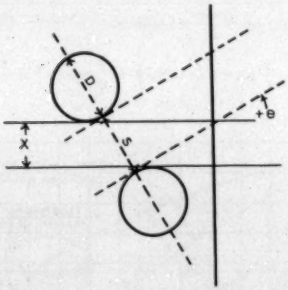
frame was then mounted so as to turn on an axis parallel to the wires.

For this screen we have

$$\frac{D+X}{D+S} = \cos\theta, \text{ whence} \tag{16}$$

$$X = (D+S)\cos\theta - D \tag{17}$$

FIG. 5.



An opening of the parallel wire grating perpendicular to the wires.

Following the same reasoning as with the first screen, the transmission with maximum unity becomes

$$\frac{n\,x\,a\,\sec\theta}{n\,S\,a} = \frac{x\,\sec\theta}{S} \text{ and multiplying (17) by } \frac{\sec\theta}{S} \text{ we get}$$

$$\text{Transmission} = 1 - \frac{D}{S}(\sec\theta - 1) \text{ or} \tag{18}$$

$$\text{Transmission} = 1 - \frac{D}{S} \text{ external sec } \theta \tag{19}$$

Fig. 6 shows in the solid line a portion of a curve experimentally determined, and the heavy dotted line the computed according to equation (19) in the following form:

$$\text{Transmission} = 1 - 0.600 \text{ external sec } \theta \tag{20}$$

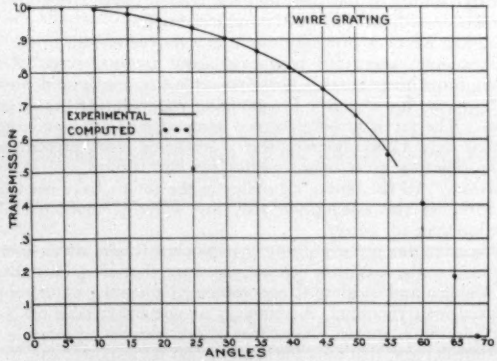
It will be seen that the agreement is excellent. This screen, while very simple from a mechanical point of view, is not so desirable from a theoretical viewpoint, as the curve bends so rapidly. Great care must be exercised in handling this screen, as a slight knock on the wires will easily bend them, changing the calibration. The wires must also be well blackened to avoid reflections.

A careful test was made with this screen to see if a lack of

parallelism of the light flux would alter the calibration over the range shown. As wide a deviation as would likely be met in practice was tried and did not alter the above curve.

The above curves are not intended to take the place of an arbitrary calibration of each screen when put into use, but it is frequently of considerable aid in such a calibration to know in advance what sort of a curve to expect. Therefore it is hoped the above may be of assistance to anyone using these screens in the future.

FIG. 6.



An experimental and theoretical calibration curve for the parallel wire grating.

The thanks of the author are due to Dr. H. E. Ives and Dr. Enoch Karrer for numerous suggestions.

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Physical Laboratory
The United Gas Improvement Company,
Philadelphia, Pa., July, 1915.

Water Power in Washington Enormous. ANON. (*U. S. Geological Survey*, Water-supply Paper No. 369.) Not every one realizes that Washington is one of the three States credited with having the most water power, or that the streams of the Pacific coast states furnish about 40 per cent. of the total estimated available water power of the United States. Eventually hydro-electric power must be a dominant factor in the development of large manufacturing enterprises in these states.

The United States Geological Survey and the Washington Board of Geological Survey, of which Governor Ernest Lister is president and Prof. Henry Dandes is geologist, are coöperating in investigating the water supply of the state and the related physical features that affect the development of power and irrigation.

Yakima River is probably the most valuable stream in the state. It can supply water for irrigating about 650,000 acres of land, besides furnishing 132,000 horse-power continuously and an additional 155,000 horse-power for pumping water during the irrigation season. The fact that only 300,000 acres of land are now irrigated, and that only 14,000 horse-power is available from present power plants, indicates great opportunities for agricultural and industrial expansion. All the power estimates in the report have been based, therefore, on the assumption that the water is more useful for irrigation than for power.

The estimates given indicate that Naches River, which joins the Yakima just above North Yakima, can furnish more power than the main Yakima and Clealum Rivers combined when the water supply is regulated for irrigation. A summary of power available on Naches River and its tributaries shows that 97,900 horse-power can be used continuously, and that an additional 62,000 horse-power can be used during the irrigation season for pumping water to lands which can not be served by gravity systems. Most of the power sites on Naches River will require relatively short transmission lines for the delivery of energy.

The essential feature of the scheme of development followed by the United States Reclamation Service is that providing for the use of stored water to supplement the supply when the streams are at low stages, a feature involving the construction of five large reservoirs having an aggregate capacity of 1,069,000 acre-feet of water. Two of these reservoirs have been completed and work on a third is well advanced. These reservoirs will be used exclusively for irrigation, but a number of smaller reservoirs can be used for power and will provide also for an increase in the water available for irrigation.

A copy of Water-supply Paper 369 may be obtained free of of charge by applying to the Director, U. S. Geological Survey, Washington, D. C.

PRODUCTION OF LIGHT BY ANIMALS.*

BY

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LUMINOSITY IN THE ECHINODERMS.

This large group of animals seems to be very near to lacking any luminous members. The class crinoidea show no such examples, although they nearly all live in the deep sea, where the luminous animal appears especially apt to develop, or, to put it more correctly, where animals appear more apt to develop the power of producing light. Also they would quite surely be found in such a position if they had this power, because the deep-water dredging is done from large boats, and the hauls of the dredge, taking hours to come to the surface, often arrive on board the vessel in the night time, when the expectant scientists would see any light and be able to pick out any luminous form and report it.

Among the class asteroidea we have one genus, several members of which have been reported as showing light, the genus *Brisinga*. Mangold denies this, however, and the subject seems to need accurate observations which should be made. It appears that the deceptive appearance of light is due to refraction phenomena caused by the structure of the animal's integument. Still more doubtful is a report that a member of the class holothuroidea is luminous. This very old report (by Ehrenberg) is so obscure that it is not certain whether he refers to the echinoderm of that name or whether he is using the very old name for *Physalia*.

Again we come to a doubtful case in the class echinoidea. These are the well-known "sea-urchins," and among them is a common tropical species, *Centrechinus setosum*, formerly *Diadema setosum*. Many observers have noted on this animal, whose various species are usually of a deep blue-black color, a series of bright blue, iridescent points or dots extending in lines over the upper surface of the body. The largest of these spots are found.

* Continued from page 261, February issue.

one each, on the genital plates. Also rows of them extend down on the interambulacral plates between the bases of the long spines. They number from one to two thousand altogether, and are slightly raised from the surface, this condition being due to the thickening of the epidermis at this point.

In section under the microscope these spots show a series of hexagonal prisms of transparent refractive material extending from the surface down to the base, where they are fitted into cup-shaped cells whose cytoplasm is filled with a black pigment. The whole structure lies directly upon the general nerve-tissue layer that covers the whole body under the epithelium. A large number of nerve ganglion-cells are found in this nerve-tissue layer at the point upon which the organ lies.

Two functions have been attributed to these organs. The Sarasin brothers and others have said that they were compound eyes, while Ludwig and Haman have taken them to be luminous organs. It must be remembered that both eyes (light-receiving organs) and photophores (light-giving organs) often have the same accessory structures as lens, iris, reflectors, or protectors of some kind. They are, therefore, often confused with eyes in the more specialized forms, especially when examined in the dead specimens, and we will meet with other doubtful forms in our future studies of the higher animals, such as fishes, crustaceans, worms and mollusks. Many cases have been formerly identified incorrectly as one or the other kind of organ and are now known correctly after careful study. In this case we have observations that point both ways, and very careful study is necessary in the future to decide which these organs on this sea-urchin really are. The case seems to be almost decided by observations and experiments made by Dr. L. R. Cary, Dr. A. G. Mayer, and the writer as follows: Fresh living *Centrechinus* were examined in their habitat on the coral reef at the Tortugas laboratory of the Carnegie Institution and in full sunlight. These animals have very long, sharp spines which pierce the flesh of any enemy that happens to touch them, however, lightly. When a hand was passed over them so as to intercept the bright daylight, all the spines on the creature's body were moved so as to point directly at this hand. If the hand was moved, the spines followed it slowly. Thus it was shown that the organism could see in all directions and could distinguish the direction of light—

a work that requires a fairly well organized eye. Since the light-blue spots were the only eye-like organs present, it seems that sight must be their function.

Dr. L. R. Cary, at the writer's request, took these sea-urchins and attempted to stimulate them to luminosity in the dark by both mechanical and chemical means. He failed to get any luminous response. On the other hand, we have the observations of Dörderlein, who, upon taking the animals from the water, saw a beautiful light at the approximate points where the blue spots are found. It is possible that he observed the creature in a half light whose rays were collected and focussed by reflection from the optical apparatus of the blue eyes; or the organism may have both eyes and light-producing spots. The writer and Dr. Cary have both seen this reflection effect in bright daylight, but not in dim lights. In conclusion it may be said that this sea-urchin most probably has eyes, but no light-producing organs.

In contrast to the four classes mentioned above we find in the fifth class of echinoderms, the ophiuroidea, that nearly all of its members, called the "brittle-stars" or "snake-stars," have well-defined light-producing organs (see Fig. 1). This power has long been recognized in them, as many of their specific names will show, such names as *Phosphorea, Noctiluca,* etc., being common.

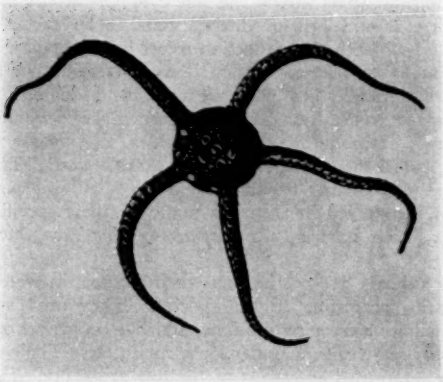
These animals live on the bottom of the sea, in water of various depths, according to the species. They are capable of rapid crawling or creeping motions, and live on gravel or among the stems of sea-weeds or under loose rocks, etc. Their crawling motion is performed by means of the five arms, one of which is held out straight before or behind, while the other four become arranged as two symmetrical pairs that are alternately advanced and pushed backward, thus moving the disk-shaped body forward.

The fact that these animals could light has not been announced as long ago as in the case of some of the other organisms treated of in this work. Nor were the early announcements more than mere mentions of the fact that the *Ophiurians* could shine. The names of some of these more or less superficial observers were Sokolow, Awerinzew, MacIntosh, Godlewski, Viviani, and Tilesius. As an intermediate group of somewhat more careful observers came Wyville Thompson, Panceri, Quatre-

fages, and Molisch. Lastly, in recent years, we have four investigators, Mangold, Reichensperger, Trojan, and Sterzinger, who made careful studies of these interesting animals with reference to the light that they are able to produce and have given us a fairly complete knowledge of the structures that represent the light organs.

Not all of the species are luminous, but the majority appear to be so. The light is fairly strong, and the various reports show that it is bright green in color. The animals show it only upon

FIG. 1.



Photograph of a brittle-star or Ophiurian, *Ophioglypha bullata*. (After Hertwig.)

the usual stimulations by chemical, mechanical, and electrical methods. Fig. 2 shows some brittle-stars as they appear when illuminating in an aquarium or in the sea. Before describing the parts of the animal from which the light emanates it may be well to briefly describe the plan upon which the creatures are formed (see Fig. 1).

The hollow body containing the digestive, reproductive, and excretory organs is a round disk, and from this central part five long, slender arms branch out. These arms are solid and composed of a series of segments that grow smaller in size towards

the tips. Each segment is formed of a number of plates that may be described very roughly as a dorsal, a ventral, and two lateral plates (see Fig. 3). Two long, fleshy feet and two smaller feet come out of openings in the outer edge of the ventral plate, a number of spines (ten in *Ophiopsila annulosa*) protrude from each lateral plate, while the dorsal plate is bare of appendages. Fig. 4, 1, is a diagram showing the relations of spines and feet to the plates in a segment as seen in a sectional view of the arm.

Wyville Thompson described the light as appearing on the

FIG. 2.

Picture drawn to show the appearance of brittle-stars shining on the bottom of the sea. (Original drawing by E. Grace White from descriptions by Sterzinger, Mangold, Trojan, Molisch, and the author.)

dorsal part of the disk and arms in *Ophiacanthia spinulosa*, but in the various other forms studied by the four recent investigators mentioned above it appears to be confined to parts of the arms alone, it being difficult to define these spots exactly. Sterzinger states that it comes from the ends of the longer feet, while the others find that it probably comes only from the little plates from which the spines are given off and from the lower parts of the spines themselves.

Mangold shows this in one fairly conclusive manner (see Fig.

5) by first examining portions of the arms in a good light to get the form of the structure and then making another examination in the dark and sketching in black the shape of the lighted regions. He also worked in the same way to determine the location of the light in several other *Ophiurians* found in the waters of the Bay of Naples. The following list will show the result of his work, as well as the apparently trustworthy external observations of some other writers:

Ophiacantha bidentata.—Light appears on the spines, on the basal plates of the spines, and on the lateral plates (Sokolow).

FIG. 3.

Dorsal or top view of part of the arm of a brittle-star, *Amphiura squamata*, to show the spines, plates, and feet. *sta*, spines; *f*, foot. (After Sterzinger.)

Ophiacantha spinulosa.—Light appeared on specimen brought up fresh in the dredge. It was seen on the edge of the body disk and moving inward to the middle, also it appeared at the tips of the five arms and moved inward toward the body (Wyville Thompson). This latter account should be re-investigated.

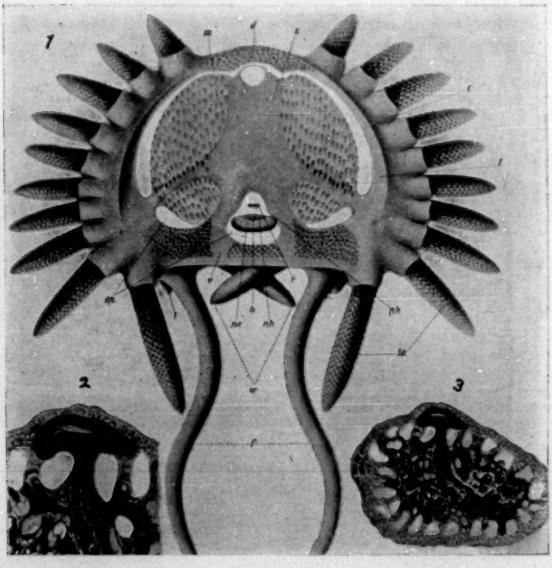
Amphiura squamata.—The light appears only on the proximal portions of the two basal plates of the spines on each segment.

Ophiacantha spinulosa.—The light appears to come from the ambulacral feet, according to Trojan.

Amphiura filiformis.—Only the spines light in this species, as described by Mangold.

Ophiopsila annulosa.—Here Mangold states that the light is

FIG. 4.



1. Semidiagrammatic view of a transverse section of an arm of the brittle-star *Ophiopsila annulosa* to show the relations of the plates, spines and feet. *d*, dorsal plate; *v*, ventral plates; *l*, lateral plate; *la*, spines; 2 and 3 represent stained microscopic sections of spines at points that show the mushroom-shaped reservoirs in which the luciferine from a number of light cells is stored. (After Trojan.)

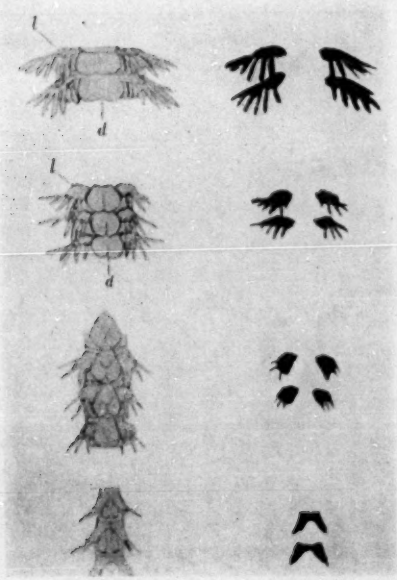
produced from the entire ventral plate, the lateral plates, and all the spines. Also it appears to come from the ciliated feet.

Ophiopsila aranea.—A much more limited area was illuminated in this form than in the last. Only the proximal part of

each lateral plate bearing the spines was involved, the distal portion remaining dark (Mangold).

Amphiuria chiajei.—No light shown according to Mangold. Histological studies have been made by several investigators

FIG. 5.

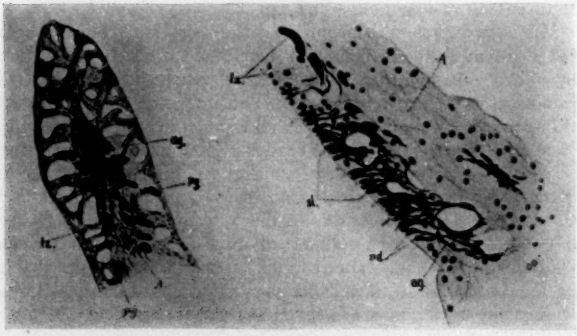


Diagrams of several segments from different parts of the arm of the brittle-star *Ophiopsila annulosa* to show the regions that are luminous during light production. On the left are seen the segments as seen in daylight. On the right is marked in black the shape and extent of the luminous areas of these same segments when the animal is excited to luminosity in the dark room. (After Mangold.)

to determine the cells or tissues that were the seat of the secretion of the luciferine and also to find out if it was an internal or intracellular light production, or if the luminous material was forced out of such cells and oxidized in the sea-water.

Reichensperger and Trojan examined sections of all of the above listed forms and from among several kinds of cells picked out one particular variety that seemed to be the specific cell for light production. This cell (see Figs. 6 and 7) is large, it lies deep in the tissues of the spine or plate, its cytoplasm is filled with granules that appear to stain in a measure like those of other light cells, and both observers agree that the heavy cell body stretches out into a prolongation that reaches to the surface of the body. They disagree, however, as to whether it opens through the very thin cuticle at this point. Such openings seem to be present, although

FIG. 6.



Section through a spine of *Ophiopsila annulosa* (left) and through part of a lateral spine of *Amphiura filiformis* (right) to show the light cells as stained with a dark stain. *lz*, light cells; *ag*, ducts; *pd*, enlarged reservoirs on distal portion of duct. (After Reichensperger.)

very small, but their presence does not altogether settle the question as to the exact site of the light production. The observations and experiments of most of the observers point to the fact that no secretion is discharged that can be rubbed off on the fingers and continue to light for even a fraction of a second. Therefore, Trojan concludes that the light must come from inside these cells. Mangold points out that if this is true the light must come only from the distal part of the cell, at a point just under the cuticle where the prolongation of the cell, which has been called its duct, is perceptibly enlarged to form a sort of reservoir. In

this way the light would appear to come from the exact areas as determined by Mangold, because the secreting bodies of the cells themselves are scattered quite widely, while their long ducts are collected so as to open well within the designated areas. Or it may prove that the luciferine is discharged, but is consumed so instantly that one sees no trace of it outside of the body.

Trojan describes a modification of the small storage spaces found on each light cell, as a mushroom-shaped cavity under the surface of the spine (see 2 and 3, Fig. 4). Into this several light cells seem to empty, although Trojan declares he has not seen this, and if this is the seat of light production, the light ought to appear as a series of larger spots on the surface of the light areas.

The idea expressed by some that the secretion from the light cells is drawn from the cells and distributed through the tissues, particularly through the muscle tissue, where it produces the luminosity, is evidently incorrect. The internal structure of the light cells seems not to have been well worked out. Trojan speaks of a nucleus, but he has left the reader in doubt as to the structure of this nucleus, from both text and figures, in which no nucleus is designated or distinguished in any way from the vacuoles that are pictured. Reichensperger, on the other hand, has designated these spaces, one in each cell, as the nucleus, and shows a weak nuclear membrane and some chromatin structures. It is probable that the processes of decalcification have injured the staining power of the nuclei or even their structural features.

LIGHT PRODUCTION AMONG THE LOWER MOLLUSKS.

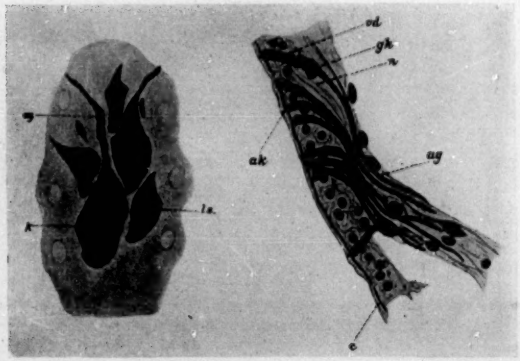
Referring to the lower mollusks as all classes exclusive of the cephalopoda, or squids and octopus, we find that in these four classes, the Amphineura (the sea limpets), Gasteropoda (slugs or snails), Scaphopoda (sea teeth or tooth snails), and the Pelecypoda (bivalved mollusks), there are remarkably few luminous forms. In fact, only two genera are decidedly well known as being able to light brightly, the gasteropod, *Phyllirrhœ bucephala*, and the pelecypod, *Pholas dactylus*. Remarks on the reported autogenous light from some of the other forms will be made at the end of this chapter.

Phyllirrhœ bucephala is an opisthobranch gasteropod of small size that has assumed a distinctly pelagic form of life, living

on the surface of the warm seas of the tropics and having adapted itself to this life by the development of transparent, watery tissues and a habit of swimming. When first seen in a glass dish among the numerous other animals taken in the surface tow net on the open parts of the Mediterranean Sea and South Atlantic Ocean one cannot for a moment realize that it is a gasteropod mollusk, although a closer inspection soon proves it to be so.

Owing to its aberrant form and habit, which, as has been said, distinguish it from the great majority of other gasteropod

FIG. 7.



Sections through a lateral spine (left) and a foot papilla (right) of *Ophiopsila annulosa* to show the light cells (left) and their ducts and reservoirs and openings (right). Letters same as in Fig. 5. (After Reichensperger.)

mollusks, *Phyllirrhœ* has been much studied as to its morphological organization and histology. In fact, the work of Eschscholtz (1825, 1834), Quoy E. Gemaird (1851, 1853), Cantraine (1841), Souleyet (1846), Leuckart (1851, 1863), Krohn (1853), Muller (1853), MacDonald (1855), Schneider (1858), Costa (1863), and many others, on its structure and comparative morphology have made it a zoological classic, as its figure on the pages of many text-books of zoology will testify. Owing to the fact that these workers always saw and studied the living animal

in daylight, however, no one of them seems to have been aware of its light-producing power.

When the creature is left at rest in an aquarium of fresh sea-water of the proper temperature to rest until nightfall, and is disturbed in the dark with a stroke from a glass rod, it gives off a brilliant light in which its entire shape as well as the outlines of its digestive tract and reproductive glands, etc., are plainly visible (see Fig. 8).

FIG. 8.

Illustration depicting the appearance of *Phyllirrhœ bucephala* as it appears in the sea when lighted. Two individuals out of the six are shown in the state of maximum illumination. (Drawing by E. Grace White after description by Panceri, Trojan, and the author.)

Four men have studied this mollusk with special reference to its light-producing power: Panceri in 1873, Putter in 1905, Vessichelli in 1906, and, most carefully of all, Trojan in 1910, in an article dealing with both the physiology and the structure of the light organs.

Panceri's work was of high scientific value, considering the period in which he worked. Nevertheless he fell into many errors that have been corrected by Trojan, who also made further ad-

vances in the subject. The method of stimulation shows many interesting features.

Like many other of the forms we have noticed, the creature swims about and shows no trace of light if not disturbed. Upon the least disturbance, however, such as the gentle shaking of the dish or a touch with a needle or a glass rod, the organism lights up suddenly, all parts of the outer surface at once. The light then fades gradually until it disappears in about ten seconds. One must have care in using the mechanical stimulation on account of the extreme delicacy of the transparent tissues of the animal. Fig. 8 shows this condition of lighting well.

Both chemical and electrical stimuli were used by Panceri and Trojan to study the lighting. Fresh water, and especially distilled water, furnishes one of the best means of getting a strong light that lasts for fully two minutes. Dilute acids and dilute ammonia both gave excellent results, although all the chemical forms of stimulus kill the creatures at the end of the lighting period. Weak organic acids or mineral acids will cause light to be shown for as much as three minutes. Ammonia causes a bright flash, but also a very short one. All these chemical stimulations not only kill the animal, but also render its tissues unfit for further histological work.

Panceri used the electric current as a stimulus with no success. He probably did not have the proper apparatus for applying it. Trojan found it to be the best means of studying the light, because it could be used a number of times without injuring the organism in the least. His method was to take the *Phyllirrhœ* out of the water, on account of the chemical changes in the water, and to apply non-polarizable electrodes, leading the current from Bunsen plate batteries with an inductor. By applying the current slowly or quickly he could get a weak or a sharp light, and, after allowing the animal to rest, could repeat the experiment.

When stimulated in this way the creature lighted strongest on and about the head and anterior part of the body; less so on the posterior part of the body and on the feelers. The light was well marked on the upper and lower edges of the body so as to outline it plainly. Also several very large points of light were visible on the middle of the sides, both before and behind. Fig. 8 shows these points clearly. With the naked eye the effect was that of a general illumination, except that the large points on the middle

stood out. With a magnifying glass, however, or with a low power of the microscope, it can be seen that all of the light comes from very many, mostly small, points. Further, these points are not all constant in their brilliancy, but the light comes and goes—glimmers, as it were—giving the effect, on the whole, of a constant glow when not too closely examined.

Trojan, in looking for the histological structures that produced the light, noted that the lights were small and thickest set on the contours of the body; that there were not so many on the feelers, and that the few very large ones were in the middle position on the sides. He therefore cut transverse sections and examined the outer integument of these to find some structures that would correspond to the size and position of the points of light. Such organs would undoubtedly be the points of origin of the luminosity.

The body was bounded by a simple epithelium and, at intervals, certain cells had become glandular in nature and had been depressed from the epithelium and their proximal ends sunken deep in the connective tissue of the animal's body. This condition was necessitated by the greatly enlarged size of the cells, whose distal cytoplasm had become filled with secretion. Fig. 10 shows the different kinds of cells so found.

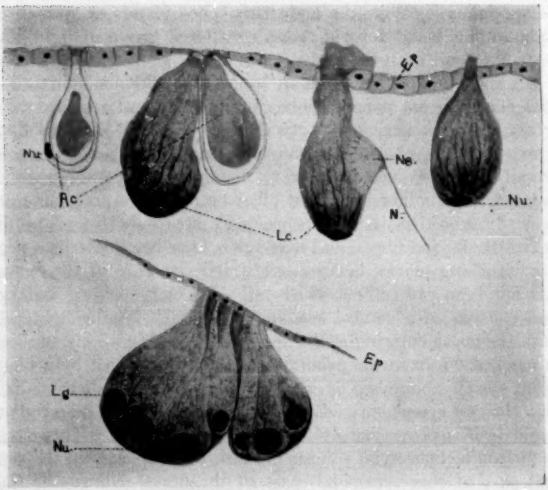
Two principal kinds of these cells are described by Trojan. The first is somewhat the larger, averaging 30 microns long and 18 microns wide (Fig. 9, *Lc*). The cell wall is not distinct from the included mass of secretion in most preparations. This cell wall includes the cytoplasm of the unit, and the nucleus lies at or near the proximal end of the cell in this thickened cell wall and cytoplasm. Lines of a denser nature spread in an irregular radiating way from the area in which the nucleus is placed, and, becoming smaller, fade away about half way toward the distal end of the cell. The nucleus, cytoplasm, and cell wall, as well as the radiating lines in the cytoplasm, all tend to stain deeply with iron hæmatoxylin, especially the nucleus and the lines.

The contents of this cell form a mass or plug of finely granular material whose outer surface is much mixed up with the inner reticular surface of the cell body (walls). This mass protrudes from the distal end of the cell, where its throat-like distal end opens through the surface as a small pore. In many cases that mass has been partly or almost entirely discharged and only a

remnant is left in a proximal position. The granular material stains deeply with such stains as iron hæmatoxylin, thionin, mucicarmine, and mucihæmatin. In this staining power, in its granular state and in other ways, it agrees with the secretions of lighting cells in some other forms, and it seems probable that these cells are the lighting cells of *Phyllirrhœ*.

Two other factors, make this seem even more probable. The

FIG. 9.



Microscopic sections taken vertically to the surface of the body of *Phyllirrhœ bucephala* to show the tissue structure in the light-producing regions. *Ac*, albumen cells; *Lc*, light cells; *Lg*, light glands composed of two or more light cells; *N*, nerve; *Ne*, nerve-ending; *Nu*, nuclei. Modified after Trojan.)

cells in question seem to correspond in number and in position to the light spots as observed on the living animal, and the innervation of these cells as described below seems to make the fact quite certain.

Transverse sections of the body show the larger number of these light cells on the upper and lower border of the body where the light is brightest. Also the cells are small here and close-

set, which corresponds to the appearance of these light spots in the same place. Then, again, the localities occupied by the few very large light spots were examined by Trojan, and here he found the interesting fact that several light cells had united as a gland to form a single point of light production (see Fig. 9, *Lg*). From two to as many as twenty cells are sometimes thus united. Their ducts do not form a common opening of any extent, but they do pour out the secretion at what is practically a single point. In this interesting animal we can see the process of specialization going on and many-celled glands or specialized light organs being formed from a scattered group of light cells distributed all over the body.

A most interesting point in connection with its light cell is that each cell has a nerve-fibre coming to it and attached to it by means of a nerve-end organ (Fig. 9, *Ne, N*). This fibre comes from some internal ganglion, and in most cases can be traced some distance back from the light cell to a branching point where another branch or other branches run to other light cells. Connective-tissue cells are very sparingly found on the nerve-trunks and fibres, and nerve-cells have been described near the branching points, but the origin and structure of the nerves has not been carefully worked out. The nerve-ending is large and consists of a conical swelling on the side of the light cell, with the nerve entering at the apex (Fig. 9, *Ne*). This swelling is marked off from the general cytoplasm of the cell by a plane from which a number of short, equally-placed rodlets radiate into the cell cytoplasm and fade in its substance. These rodlets begin in this plane sharply and are equally spaced. They stain with iron hæmatoxylin. A small, dark body appears in the central part of this pyramidal mass of the nerve-ending. Trojan calls it a small nucleus, but it should be further studied and may not be one.

We can now understand to some degree how this cell may operate. It undoubtedly starts the release of light energy in response to a nerve impulse. This is very apparent when we remember that the whole number, several hundreds or thousands, of the light cells suddenly blaze out at once, no matter how or where the animal's body may be stimulated. This points to a central ganglionic control, and careful experiments should be undertaken to assure ourselves that this assumption is correct.

Such experiments should include a more careful set of local and general stimulation experiments, as well as the cutting of designated nerve-trunks and the artificial control of the several ganglia or their local destruction. The animal, although small, is very transparent and should lend itself readily to such tests.

When the nerve impulse has once arrived at the cell, however, other interesting questions arise. Is any specific chemical or vital action set up that causes the appearance of the light? Or is the result of the nerve discharge merely a muscular and mechanical one which causes the approximation of the luciferine or oxygen, and of the necessary enzyme, oxidase, or organic catalytic agent, all of which are necessary for the appearance of the light?

A closer examination of the structure of the cell will help us to get some working hypothesis. In structure it is undoubtedly a gland-cell with its nucleus pressed down against the proximal surface and a large mass of secreted material filling its internal cavity and being pressed up out of a distal pore so as to be forced out into the surrounding water. This condition can be seen in two of the light cells in Fig. 9. Further, the presence of the dark-staining strands radiating from the nuclear position, and the rods that radiate from the nerve-ending, may indicate the presence of muscular element in the cell which could be used through the stimulus of the nerve discharge to press out the secretion. This assumption is not even necessary, however, as we know many unicellular glands throw out their contents upon nerve stimulation without the presence of any such fibrils. The perinuclear fibrils may, and probably are, secretion fibrils, and the rods around the nerve-ending may be associated with the reception and distribution of the nervous discharge.

No one has established the fact that a luminous secretion has been thrown off as in *Pelagia* or *Chætopterus*, but it may well be that the luminous action can take place at the instant of discharge and the material, when once separated from the body surface, can already be exhausted. Or the light-producing action can even take place in the distal part of the cell before the substances have emerged from the cell pore.

The presence of other and different cells, often associated with the light cells, must be considered. From their affinity for dyes such as eosin, Trojan took them to be albumin cells. They

appear in Fig. 9, *a.c.*, and show a different structure from the light cells. They, too, are gland-cells, but in some cases the efferent duct or pore was not seen. In others this duct was visible. The possibility remains that these structures secrete the necessary enzyme, and their frequent proximity to the light cells points to some such use. On the other hand, they are hardly numerous enough, and many light cells are without them. They may be poison cells, and that appears the more probable when we remember that the animal is undoubtedly poisonous to other creatures and that these albumin cells seem the only or, rather, the easiest way of explaining that.

The color of the light has not been studied at all. Mention has been made of it as "white" and "bluish."

Several other pteropod, pulmonate, and heteropod mollusks, as has already been mentioned, have been reported to light, but no scientific study of them has been made. We can with some confidence believe that a small proportion of these reports have a foundation in fact. Against it is the truth that the mollusks in general, the cephalopoda excepted, show but little inclination to produce light. In favor of it, we must consider that the pteropoda and the heteropoda are surface-swimming pelagic forms, and that all such groups are peculiarly apt to develop the light-producing power. I should expect the pteropoda especially to have some species that have developed a luminosity.

Turning now to the pelecypoda or bivalve mollusks, we find that great exception that proves the rule in a mollusk which we would least expect to possess a luminous organ. This clam-like species *Pholas dactylus* is a form that buries deep in hard mud and soft stone or rotted wood and lives deep below the surface. It is possessed of a long, extensible siphon which it protrudes up through the ground until its tip opens at the surface and is used to provide the creature with an incurrent and an excurrent stream of water bearing the life-giving oxygen and the food supply of diatoms and other small plants and animals.

When this mollusk is opened, it is found that it possesses three pairs of well-developed, simple, and very powerful light organs (see Fig. 10). Each organ consists of a modified region of the integument, and they are distributed as follows: One pair exists as two long, somewhat narrow strips placed symmetrically and laterally on the siphonal septum in the excurrent canal. They

occupy two-thirds or more of its length, and are placed nearer the base than the tip of the siphon. Another pair are two triangular regions on the outer sides of the two retractor muscles, where they become part of the body mass. The third are long, narrow organs found on the inner edge of the mantle and touching each other by their median ends so that they form a single line, bent into a roughly horse-shoe-shaped form that partly surrounds the foot opening. Fig. 10 shows the general position of these organs as seen in the dark after the animal has been cut open and its shell spread somewhat apart.

In structure all these organs are almost alike. The integument is thickened at this point, and the simple epithelium that

FIG. 10.

Panceri's figure illustrating the region of luminous tissue in *Pholas dactylus*. The animal is supposed to be cut open from the ventral side. (After Panceri.)

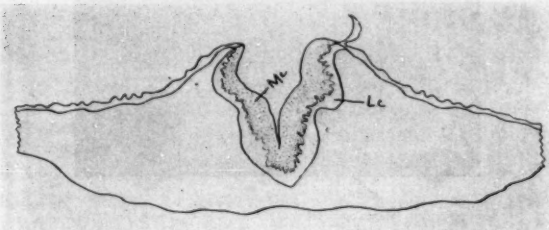
covers all parts of the body is modified at this point so that it consists of three layers (see Figs. 11 and 12). The first and outer layer is made up of the original long, simple epithelial cells of this region slightly modified. They are somewhat longer than usual, and the cilia that they bear have become over twice as long as in other similar places. These cilia each emerge from the cell from a tiny granule in its distal surface and pass through a thin, delicate cuticle to the outside. Inside the cell they have parallel, rod-like, protoplasmic continuations such as have so often been described in ciliated cells. These structures are parallel except where they make room for the nucleus.

The next layer of the organ lies just below this and is made up of a mass of unicellular glands more or less massed together and with their distal ends prolonged into long, thin ducts that push between the epithelial cells and open to the exterior (see Fig. 12). A good-sized nucleus is found in the proximal base of this

cell, and its body is mostly taken up by the secretion, which is a vacuolated mass that takes iron hæmatoxylin, hæmalum, muci-carmine, and other similar stains deeply. Förster takes the view that these cells produce nothing but mucin. The writer is not yet willing to admit that such is the case, for reasons which will be given later on.

The third and deepest layer is also a set of unicellular gland-cells derived in the same way as the last, from the surface epithelium, but farther removed from the surface by a greater elongation of the duct (see Fig. 12). These ducts, of course, pass between the mucin cells to effect an outlet through pores between the epithelial cells just as the ducts of the mucin cells do. The

FIG. 11.



Section of one of the luminous organs in *Pholas dactylus*. *Lc*, region of luminous cells; *mc*, region of mucin cells. (Outline drawing by E. Grace White.)

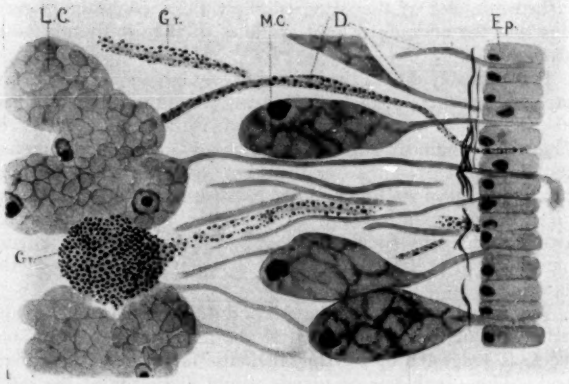
cell bodies are, under normal conditions and when not too much crowded, elongate oval in shape. In many cases, where numerous and especially where filled with much secretion, they become many sided and, on account of their thin walls, hard to distinguish from one another. They average roughly about 40 microns long in the body and 30 microns wide, while the ducts measure from 50 microns to 450 microns, according to the size of the organ and in which level of the general light cell layer their cell parts are situated. They do not always form a single layer, but from the exceptional single row of cells up to as many as seven irregular rows deep in the larger organs. Each cell shows a single nucleus of irregular outline and containing a single body, a combination of plasmosome and chromatin, round

and homogeneous. The nuclear membrane is well defined and the nucleus measures about 4.7 microns, while the spherical chromatin-plasmosome is very uniformly 2.1 microns in diameter.

The cytoplasm of the cell is of uniform structure throughout and shows a series of areas of a homogeneous, apparently fluid material. This substance is inclosed in the meshes of an alveolum of a firmer and darker-staining material whose spaces are polyhedral in form, much as a mass of soap-bubbles would be.

Förster describes some interesting changes in the contents of

FIG. 12.



Enlarged portion of a microscopic section of one of the luminous organs of *Pholas*. *mc*, mucin cells; *lc*, light cells; *d*, ducts of light cells; *gr*, granule mass in ducts and cells. Cilia and cuticle not shown in this preparation. (Original drawing by E. Grace White.)

this cell just before it becomes ripe for discharge. According to his account, the contents of the alveoli change from a homogeneous, fluid, non-chromatic condition into a series of small and very uniform granules which measure about 3 microns by 2.1 microns. These granules have a definite structure with an internal core and an external cortex in which certain dark-staining bodies are present.

When fully ripe, Förster shows these granules as entirely filling the cell and in contact with the nucleus. This is an unusual

condition in a gland-cell of this type, and the more so that each cell should show a complete state of ripeness such as is usually found only in cells that do not regenerate but die with the discharge of their ripened contents. That these oval granules are the real luciferine would appear to be the case, since they are visible as points of light in the discharged secretion.

Another possibility is that the luciferase is also secreted in the lower layer (light cells of Förster) and is discharged through the same ducts as the luciferine, the light being inhibited up to the time of discharge by the absence of oxygen. In regard to such a possibility the writer has often seen a homogeneous non-staining material coming up and pouring out of the light cell ducts. The finished granules of the secretion show the same staining reactions that the undoubted light granules of the fire-fly and other forms do.

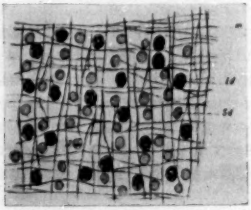
It is probably due to the comparatively large size and definite shape and hardness of these luciferine granules that the light persists so long in water that comes from the mantle cavity of *Pholas*. If a number of these mollusks are cut open and washed about in a pail of salt water the whole body of water becomes brightly luminous and the light persists for some time. If a portion of the secretion is examined with a low power of the microscope or with a strong hand lens that light is seen to emanate from a multitude of points which represent the freed granules of the luciferine.

We must here consider the relation of the mucin cells to the discharged luciferine granules. If the mucin cells secrete only mucin, as suggested by Förster, their use might be easily understood. Thus, both sets of glands would discharge at the same time, and as their ducts open at alternate points, closely intermingled on the surface of the organ (see Fig. 13), we must expect to find the secretions of both mixed with each other. This appears to be true, and in that case the rapidly-expanding mucus would act as a carrier for the heavy luciferine granules and would enable them to be carried out of the excurrent canal with the respiratory stream. But we have not thus accounted for the enzyme luciferase which Bubois discovered in this important form. Since the luciferase is not present in the animal's blood, as in the case of the fire-fly, and since the combustion takes place outside of the body, this enzyme must emerge from the gland in com-

pany with the luciferine and exert itself on this substance in the finished secretion product. The question is, does it discharge from the light cells as a part of the secretion or in company with the granules, or does it come from the so-called mucin cells in company with a true mucus?

The writer studied these mucous cells in careful preparations of his own as well as in Förster's figures, and is of the opinion that the luciferase is a component of the discharge from these cells. For one reason is the fact that numerous other real mucous cells from all over the body of *Pholas* do not stain like these found in the luminous organ. And the contained secretion of these latter cells appears to be a mixture; an alveolum of the blue-staining mucin with contained bodies of some non-staining sub-

FIG. 13.



Horizontal section of light organ of *Pholas* taken at the level just below the epithelium. *m*, muscle fibres; *ld*, light-cell ducts; *sd*, ducts of mucin cells. (After Förster.)

stance that might be the luciferase or the spaces occupied by it in the living state of the tissues.

Both of the above views, one inclusive of the other, are possibilities, and the solution of the question forms a most attractive problem in the field of animal luminosity.

Why should an animal that lies buried in a burrow all of its life need luminous organs, and, further, why should it possess these organs in a cavity in its body? The only way in which the light could be exposed to the eyes of other creatures would be by throwing the luminous slime up through the excurrent canal of the siphon, which several observers have stated to be the way that it does. Further experimental work might be done on this problem of its habits.

The whole three organs show their light simultaneously upon any decided stimulation. This is difficult to observe, because one has to injure the animal seriously in order to expose the six organs to the eye. When opened, however, an hour or less of rest in salt water or in a moist chamber at the natural temperature of the sea from which the organisms were taken will reduce the luminous organs to quiescence, and one can then perform stimulation experiments and study the light.

Förster made a careful study of the nerves that come to the luminous tissues and found all the light organs to be well supplied with large stems that branched out and sent their fine twigs into the tissue of the organ. The exact termination of these nerves, however, was not described: whether each cell of the two layers was provided with a means of being stimulated to discharge its contents, or whether the cells did not connect with the nerve, but the latter ended on muscle-fibres which could contract and squeeze the entire organ so as to press out the secretion. While both of these methods seem possible, the writer thinks that each cell is probably provided with a nerve-ending to enable it to discharge when the general signal is sent out from the central ganglion. If some investigator would open a *Pholas*, cut the nerve-trunks on one side, and then experiment with both mechanical pressures and stimulations of the nerve ganglia, this question ought to be easily solved.

The color of the light in *Pholas* is ordinarily greenish or greenish-blue as seen in the majority of luminous animals.

(*To be continued.*)

Incandescent Electric Headlight Equipment. ANON. (*Railway Age Gazette*, vol. 66, No. 7, February 18, 1916.)—During the past few years the Schroeder Headlight Company, of Evansville, Ind., has given much attention to the development of incandescent electric headlight equipment to meet the growing demand for headlights of this type. At the present time it has on the market three types of equipment, namely, the 6-volt turbo-generator, having a capacity of 150 watts, and two 32-volt generators having capacities of 350 watts and 1000 watts respectively. The 32-volt, 350 watt system has been the most extensively used up to the present time, and has already been made standard on some roads. According to the report of a road operating in the middle West, the average cost of operation is $11.54 per machine per year.

CORRESPONDENCE.

MEMORANDUM ON OPPORTUNITIES FOR THE FRANKLIN INSTITUTE IN CONNECTION WITH AMERICAN LABORATORIES.

DR. R. B. OWENS, Editor,
Franklin Institute.

Dear Dr. Owens:

When The Franklin Institute was founded, in 1824, for the fostering of the mechanic arts, only a very few laboratories existed in America for research in applied science. At the present time there are many such laboratories, and their number is steadily increasing. Almost every technical school in the country maintains a laboratory or laboratories, and in most of these research is carried on, leading to results which find a published record.

The existing American laboratories for work in engineering are of various types, from the national laboratories of the United States Bureau of Standards and other government departments to the little establishments of private amateurs; but, from the standpoint of this memorandum, they may all be divided into two great classes; namely,

First. Those that either publish or attempt to publish their results.

Second. Those that make no attempt to publish their results.

The first class is essentially an asset to the nation and to the world. The second class is essentially an asset to individuals, or to restricted groups of individuals. The suggestions here submitted have reference only to the first class. No consideration is here given to the second or mute class of laboratories, which are mainly elements in purely commercial organizations. These have great and proper value, but are in a class apart.

The idea which it is desired to express in this memorandum is that The Franklin Institute is, by its history, position, and charter, peculiarly capable of fulfilling its functions and aiding the cause of American engineering by paying particular attention to the work of American engineering laboratories in the first class mentioned above. It is here assumed that a broad interpretation

of the term " mechanic arts," as this was used in Franklin's time, would include not only all engineering, but also industrial chemistry, economics, and applied science generally.

If we consider the work of the various American applied-science laboratories to-day, we find that work is going on healthily in each, as a separate point source. Each laboratory, as a rule, works for and in itself, as though it were the only one in the country. It is almost self-evident that the collective output would be improved and the cause of engineering advanced if these various laboratories could be coördinated, without repressing their individual initiative. What is desirable is such a coördination and coöperation between the various laboratories as should intensify their work systematically, without imposing on them either hindering restrictions or burdensome expense.

There are at least four ways in which The Franklin Institute can assist the American engineering laboratories taken collectively:

1. By giving publication, so far as it can, to the results reached in these laboratories. It does this, as I understand it, already.

2. By suggesting subjects for research to such laboratories as seem best suited for them.

3. Inviting subjects from the industries, and grants for the expenses of research.

4. By encouraging mutual understanding between the laboratories.

Theoretically, the American laboratory combination should benefit, both in individual units and collectively, by the growth of specialism, so far as it can be carried without disadvantage. For example, the Bureau of Standards has particular duties in regard to precision of research, and this calls for specialization of that type. It would probably be a great mistake for the average engineering laboratory to attempt a like degree of precision in its measurements. This specialty of the Bureau should be recognized and encouraged. Again, it is a pity to find a number of laboratories all engaging on the same subject of investigation, and none of them engaging on other equally important subjects. The Franklin Institute cannot prevent such bad distribution of labor. It can, however, make such suggestions as will commend themselves by their reasonableness, and, when a particular laboratory develops a specialty on its own account, advantage can be taken

of this to emphasize and recognize that specialty. A very large laboratory can maintain the luxury of a number of simultaneous specialties; but a very small laboratory can only expect to do good work in one at a time.

The national and local benefits which are derivable from a closer coördination and coöperation between American engineering laboratories will tend to assert themselves, if the proper psychological conditions be produced. That is, if The Franklin Institute can succeed in conveying the idea to the workers in the various laboratories that, whether they wish it or no, they form an essential collective entity, on which the progress of the country greatly depends, the laboratories will surely conform more or less to that idea, and work towards that progress, either consciously or unconsciously. If the motion can be fostered that the heartiest and most effective of competition is one which benefits the collective entity, acrimonious competition, where it may exist, would give place to a generous and stimulative emulation. These ideas can be disseminated either by editorial articles in the JOURNAL or by personal communication, or by both means, the object being to favor the collective advantage, and not the advantage of any single laboratory in the collection.

The ideal system, if it could be obtained, would perhaps be one in which the various laboratories were finally united in some very simple, flexible organization for promoting mutual activity. Each would tend to develop a certain specialty or group of specialties, and students seeking information or research along those specialties would select particular laboratories for this purpose. But no rule should be laid down to attempt enforcing any specialty upon any laboratory, or the maintenance of a specialty where that maintenance became a burden. The natural tendency to specialize should merely be recognized and encouraged. The inevitable reward would be the rate of growth in results along the selected lines of work, which would naturally be greater, in the long run, than where the efforts were scattered. The individual laboratories in the organization would naturally ask that questions on their chosen lines should be sent to them. If too many elected one and the same subject, they would soon recognize that the fair division of material among so many prevented each from making rapid progress; and so the tendency of reduplicating unnecessarily should be automatically checked.

It will probably take a long time to bring about an organized system of coöperation between the laboratories; but The Franklin Institute, if it sets itself to the task of fostering the movement impartially, is in a specially advantageous position to bring it about. In just so far as its aims would meet with success should this success benefit and redound to the credit of the Institute, which has nothing to lose if it does not succeed, and much to gain if it does not fail. The money expenses of the undertaking in its initial stages need only be very small. The effort would be principally intellectual and individual. If the movement, however, were to gain headway, the expenses should readily be met. Thus, if the engineering industries desired certain investigations made, they would be likely to apply to the Institute as the clearing-house, and offer, when necessary, a certain sum to defray the expenses. It is assumed that the information desired is outside the province of either consulting engineering, on the one hand, or of the standard testing laboratories, on the other. The Institute would then refer the matter to the laboratory committee, so as to have it assigned to the laboratories best fitted to take up the inquiry. If no laboratory volunteered, no harm would be done. If a laboratory took the matter up, the results, so far as they were attained, would be published in the JOURNAL, at least in abstract, and communicated *in extenso* to the industry. The all-essential requisite to the procedure would be that it should be conducted impartially and for the collective welfare of both the laboratories and of the industry.

In a certain sense, the ideas here suggested have no novelty, because the Institute has for years been doing the sort of thing contemplated. In offering the Boyden Premium, for instance, the Institute has already acted in such a capacity as these ideas would indicate. The novelty, if any then, lies in executing with greater emphasis and earnestness a long-existing policy, looking for evolution and coördination towards effectiveness and public welfare.

Respectfully submitted,

(Signed) A. E. KENNELLY,
Life Member.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY,
February 5, 1916.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

A STUDY OF INSTRUMENTS FOR MEASURING RADIANT ENERGY IN ABSOLUTE VALUE: AN ABSOLUTE THERMOPILE.[1]

By W. W. Coblentz and W. B. Emerson.

THE PRESENT STATUS OF THE DETERMINATION OF THE CONSTANT OF TOTAL RADIATION OF A BLACK BODY.[2]

By W. W. Coblentz.

[ABSTRACTS.]

THE first paper gives the results of an investigation of the behavior of a bismuth-silver thermopile suitably modified to measure radiant energy in absolute value. Instead of exposing the thermopile directly to the incident radiation, a blackened metal strip intervenes. This metal strip functions (1) as a receiver for absorbing radiant energy, (2) as a source of radiations (by heating it electrically) which may be evaluated in absolute measure, and, by using a constant current for heating the strip, (3) as a standard source of radiation for testing the sensitivity of radiometer, which includes both galvonometer and thermopile.

The present investigation relates to 13 receivers, made of manganin, therlo, and platinum, differing in width from 2.5 to 8 mm. and in thickness from less than 0.001 mm. for platinum to 0.011 mm. for manganin. The manganin and therlo receivers were painted with a thick coat of lamp-black, then smoked. The platinum receivers were covered with platinum black and afterwards smoked. In this manner (the same values being obtained in the two cases) it was shown that there is but little difference in the reflecting power of these two kinds of absorbing surfaces.

The method of operation is unsymmetrical in that when the receiver is exposed to radiation the heating is produced in the lamp-black surface, while in passing an electrical current through

* Communicated by the Director.

[1] Scientific Paper No. 261.

[2] Scientific Paper No. 262.

the strip the heat is generated within the receiver. However, from the data obtained with receivers differing 10 times in thickness and covered with different kinds and thicknesses of absorbing material it appears that the manner of heating the receiver has but little effect upon the final result.

For any one receiver, operated under different conditions, the precision attained is usually much better than 1 per cent. For the different receivers the maximum range in the value of the radiation constant, which was caused by two receivers giving high values, is of the order of 3.5 to 4 per cent. Excluding these two receivers, the range of values for the different receivers is of the order of 1.5 to 2 per cent. This seems to be independent of the length and width of the receiver, and of the kind of slits used.

The accuracy attained with this method of evaluating energy in absolute measure, as estimated from the departure of individual determinations from the mean value, appears to be of the order of 1 per cent. To this extent one can consider the present device a primary instrument for evaluating radiant energy in absolute measure.

The device commends itself as an instrument of precision because of its quickness of action, its freedom of surrounding conditions, its high sensitivity, and its simplicity of operation. It can be designed to suit the equipment of the average laboratory. The device can be much simplified and used as a radiation pyrometer, and in practice it is advisable to calibrate the receiver by exposing it to a black body heated to about 1000°, when it is desired to make refined radiation measurements.

The loss of energy by diffuse reflection from the blackened surface of the receiver was investigated, and it was found that there was but little difference in the reflecting power of the different surfaces examined.

The second paper gives a summary of the methods used and the values of the constant of total radiation obtained by various observers. Corrections, for losses by reflection, for atmospheric absorption, and for lack of blackness of the radiator were applied. After making these corrections to the most reliable measurements the large variations in the radiation constant had disappeared, giving a value of the coefficient which is of the order of $\sigma = 5.7 \times 10^{-12}$ watt, per cm.$^{-2}$ per deg^{-4}.

This paper gives also the correction (about 1 per cent.) for lack of "blackness" of the radiations from an unpainted porcelain tube radiator and for the atmospheric absorption in 1.2 m. of air containing a determined amount of water vapor, the radiator being at about 1050° C.

The data obtained in Part I of this paper are corrected for losses by diffuse reflection from the receiver and combined to give a value of the coefficient (the so-called Stefan-Boltzmann constant) of total radiation from a black body. The correction applied to all the data for diffuse reflection is taken as being 1.5 per cent. This correction may be 0.1 to 0.3 per cent. too high for lamp-black, but it will eliminate, in part, atmospheric absorption and the possible lack of blackness of the radiator.

The mean value of the radiation constant (corrected by 1.5 per cent.), as determined by 12 receivers, and representing 348 pairs of measurements, is:

$$\sigma = 5.77 \times 10^{-12} \text{ watt cm.}^{-2} \text{ deg.}^{-4}$$

If we exclude receivers Nos. 8 and 9, which is permissible in view of the fact that they were known to be defective, the value of the coefficient of total radiation, representing the mean of 304 pairs of determinations, is

$$\sigma = 5.74 \times 10^{-12} \text{ watt cm.}^{-2} \text{ deg.}^{-4}$$

which is but little smaller than the value obtained for all the receivers. All the determinations are given the same weight in finding the mean value. Each tabulated value represents two sets of measurements, each one of which is a complete determination, consisting of 5 to 10 or more readings when the receiver was heated electrically and when it was heated radiometrically. From the data at hand it appears that the value of the radiation constant is of the order of

$$\sigma = 5.74 \times 10^{-12} \text{ watt cm.}^{-2} \text{ deg.}^{-4}$$

or

$$\sigma = 1.37 \times 10^{-12} \text{ gr–cal cm.}^{-2} \text{ deg.}^{-4}$$

THE PREPARATION OF PURE IRON AND IRON-CARBON ALLOYS.*

By J. R. Cain, E. Schramm, and H. E. Cleaves.

IT is shown that previous work on the iron-carbon diagram is unsatisfactory because of the great uncertainty of chemical composition of the materials used. It was therefore thought necessary to produce a series of alloys of great purity to form the basis of a redetermination of the diagram at the Bureau of Standards. The general method pursued consisted in melting electrolytic iron with sugar carbon in magnesia crucibles. The electrolytic iron was prepared from ingot iron anodes in a chloride bath with or without the use of porous cups. The operation of melting the iron with carbon gave great trouble at first, because the ingots obtained were full of blow-holes and contained considerable quantities of impurities. The difficulties were overcome by melting in a vacuum furnace, and making crucibles of especially pure magnesia, made and calcined with great care at the Bureau of Standards. A satisfactory procedure was finally worked out and a series of alloys prepared of the composition Fe + C = 99.96 per cent.

THE COLORIMETRIC DETERMINATION OF ACETYLENE AND ITS APPLICATION TO THE DETERMINATION OF WATER.†

By E. R. Weaver.

A COLORIMETRIC method for the detection of small amounts of acetylene has been developed in the course of an investigation upon the determination of small amounts of water by the use of calcium carbide. The results upon the quantitative determination of water have not been satisfactory, but a simple and very sensitive qualitative test for water is easily made.

The method for the determination of acetylene has been worked out successfully. The determination is made by conducting the gas to be investigated into an ammoniacal solution of cuprous chloride containing gelatine and alcohol, and comparing the red colloidal solution so obtained with a suitable

* Scientific Paper No. 266.
† Scientific Paper No. 267.

standard, which may be either a solution of red dye or a piece of ruby glass.

After a careful investigation of the effect of varying the composition of the absorbing solution, the following procedure was adopted in making up the solution: Dissolve 0.25 Gm. of gelatine in hot water, dilute to 500 c.c. and add 500 c.c. of 95 per cent. alcohol, and 1.25 Gm. of hydroxylamine hydrochloride. To 20 c.c. of this solution add 10 c.c. of concentrated ammonium hydroxide and a small amount of cuprous chloride. After the absorption of the acetylene, the solution is diluted to 100 c.c. and compared in a calorimeter with the standard which has been chosen. The standard used in the experimental work was a solution containing chromanilbraun R, carmoisine B, and gum arabic. A more convenient, though less accurate, standard is a fixed depth of a solution of azolitmin. If 10 cm. of a solution of azolitmin containing 1 part of the dye to 2500 parts of water is used as standard, the amount of acetylene in 100 c.c. of colloidal solution may be calculated from the equation $X = 0.13y$, where X = No. of milligrammes of acetylene, and $y = 1/\text{No. cm.}$ of colloidal solution required to match the standard.

The method is very sensitive. Amounts of acetylene as small as 0.03 mg. may be detected, and amounts up to 2 mg. may be determined with an accuracy of better than 0.05 mg.

Hydrogen sulphide and large amounts of oxygen and carbon dioxide interfere with the test, but all of these may be removed by passing the gas to be tested through a hot alkaline solution of pyrogallol without loss of acetylene.

A qualitative test for water, sensitive to less than 0.1 mg., may be very easily and quickly made by bringing the substance to be tested into contact with calcium carbide in the presence of a solvent for acetylene, which is then decanted or distilled into an ammoniacal solution of cuprous chloride. Nearly all the common organic liquids are suitable for use if carefully dried. The method is applicable to a great variety of substances, and especially to volatile organic compounds. The only compounds known to interfere with the test are the stronger acids and substances, such as hydrogen sulphide, which precipitate cuprous salts from solution.

The investigation required some experiments upon the determination of larger amounts of acetylene by precipitation with

cuprous chloride and subsequent determination of the copper. It was found that in order to obtain accurate results by this method it is absolutely necessary to carry out the filtration and washing of the precipitate in the absence of air.

MODERN PRACTICE IN THE CONSTRUCTION AND MAINTENANCE OF RAIL JOINTS AND BONDS IN ELECTRIC RAILWAYS.*

By E. R. Shepard.

IN connection with the study of electrolysis and electrolysis mitigation the attention of the Bureau of Standards has been called to the past and present high rate of rail joint and rail bond failures and the consequence of such failures upon the electrolysis conditions throughout the country. With the idea of collecting information on the best present-day practices of bonding tracks a circular letter was prepared and copies were sent to 130 operating companies. The letter asked for information as to the number and types of bonds and joints in use and for the average life and causes of failure of each type; also for the manner and time of testing bonds and the criterion for replacement. Other questions of minor importance were also included.

The present paper is largely a compilation of the data submitted by 42 companies answering the inquiries, and also includes information collected by a representative of the Bureau who spent five weeks in the field and visited upward of fifty companies in the interest of the investigation.

An historical and descriptive discussion of the various types of modern bonds and joints is followed by a compilation and analysis of all available information on each type. Among the principal features brought out in the analysis of the data are the following:

Soldered bonds of all types are falling into disuse. A few companies, however, employing thoroughly experienced and careful workmen still continue to use them.

A large percentage of the many rail bond failures in past years has been the result of imperfect methods of manufacture and of ignorance and carelessness in installation.

* Technologic Paper No. 62.

Practically all types of modern bonds, when selected to meet local conditions and installed according to the best modern practices, will give satisfactory results with an almost negligible percentage of failures on joints which are properly maintained.

No one type of bond can be said to be better than all other types. Each has its advantages and disadvantages, and the selection of a bond for any particular service should be governed by the type of construction on which it is to be used, the grade of labor available for installation, and upon numerous other local conditions.

The problem of rail bond maintenance is largely that of joint maintenance. No bond can be expected to last continuously on a loose and poorly-supported rail joint.

The surfacing of all newly-installed joints and the tightening of all bolts soon after installation and at regular intervals thereafter will do much to prevent loosening of joints and cupping of rails.

Improved bolts having a high elastic limit and a great ultimate strength appear to be giving excellent results, and their universal adoption is recommended on all new work.

Difficulty has been experienced in obtaining sufficient room for concealed bonds, particularly on the smaller rails. This difficulty has been largely overcome in several of the improved patent joints now on the market. It is recommended that bonds and joint plates be selected only after laying out a section of the joint on the drawing-board and providing a proper clearance for the bonds.

The life of concealed bonds on exposed rails is much shorter than on rails in city streets, owing to the expansion and contraction in the joint on the former type of construction. Such expansion and contraction can be overcome by the use of improved mechanical joints, supplemented by expansion joints at regular intervals. It is believed that such construction would prove itself to be of ultimate economy, and is recommended, at least on an experimental basis.

Both the compressed terminal and the pin terminal types of bonds are giving excellent results where proper attention is given to their installation. The former type requires more care in the expansion of the terminal, while the latter type requires greater accuracy in the drilling of the holes. Each has its

peculiarities and should be selected only after due consideration to local conditions.

A strict adherence to the code of bonding rules given in Richey's Electric Railway Handbook is recommended.

Stranded bonds appear to be giving better satisfaction than ribbon bonds, as the conductors of the latter type are more easily separated and broken. Exposed ribbon bonds should have a clip or band at the centre of the bond to prevent this separation of the conductors.

The use of solder in connection with the application of mechanically-applied bonds will undoubtedly add to their life if the work is carefully performed. Its use, however, does not always appear to be justified, as good results under modern conditions can be obtained without it. Its use should depend entirely upon local conditions.

The use of tinned terminals and plastic alloys in connection with mechanically-applied bonds appears to be a good practice. Their use is recommended where trouble from corrosion of terminals has been experienced.

Mechanically-applied head bonds are comparatively modern and are therefore more or less in the experimental stage. However, their use is increasing, and in most installations they appear to be giving fairly satisfactory results. They are short, cheap, and easily installed. Their contact resistance appears to increase with time, but not ordinarily to the point of failure. When installed in city streets they are subjected to vehicle traffic, and some failures must be expected.

Electrically-welded bonds have a low and permanent contact resistance. Theft of this type is difficult, and, owing to the shortness of the bond and its tenacious contact, has been reduced to a minimum. Failures of the head bond from the breaking of ribbons have been quite prevalent, but are being reduced by a modification in the design of the bond.

Welded joints are being used more than ever before, but there is also a growing tendency to adopt improved mechanical joints and various forms of special joints, several of which are a combination of welded and bolted or welded and riveted joints. These special joints seem to be meeting the demands of service with fewer failures and better results generally than any of the standard types.

Power economy alone will not justify the best modern practice in bonding. Such practice, however, is justified and strongly recommended from the standpoint of good voltage conditions in the return circuit, which not only make for good electrolysis conditions, but also for satisfactory operation. The present practice of basing the criterion for bond replacements upon a joint resistance which is defined in terms of the resistance of a given length of adjacent rail is shown to be somewhat irrational, but owing to its simplicity and ease of application the continuation of the practice is recommended. From six to ten feet of rail as the limiting resistance for rail joints is shown to represent good practice, and it is recommended that these figures be not exceeded under ordinary conditions.

The paper calls attention to the fact that the problem of track bonding is in a state of evolution. New inventions and improvements in methods and practices have been so frequent during recent years that many types of bonds and joints can still be said to be in the experimental stage. Carefully-kept records and a free interchange of experiences on the part of the operating companies will do much toward the establishment of definite and standard practice in this particular field.

The paper contains 34 figures.

THE LEAKAGE OF CURRENT FROM ELECTRIC RAILWAYS.*

In this paper the theory of the leakage of current from electric railway tracks is developed mathematically.

Assuming, first, a single track of uniform construction, and, later, a track whose sections vary in conductivity, leakage resistance, and loading, the effects of rail and leakage resistance and of the length of the line on the distribution and amount of leakage current are calculated for systems with both grounded and ungrounded negative buses.

Curves are plotted showing the effects of the principal variables in the formulas developed. The conclusions with respect to electrolysis to be drawn from the formulas and curves are discussed and tabulated. The paper contains 14 figures.

* Technologic Paper No. 63.

THE DETERMINATION OF OIL AND RESIN IN VARNISH.*

By E. W. Boughton.

EXISTING methods can be classified as follows: (1) calculation of the oil content from the determined glycerol yield; (2) separation by the use of solvents; and (3) esterification methods, some of which include separation of oil and "gum" by petroleum ether. It is shown that method (1) gives fairly good results except with varnish that contains Chinese wood oil. The following methods under (2) were investigated: precipitation of the "gum" by petroleum ether, extraction of oxidized films with chloroform to separate oil and resin, and a combination of these steps. These methods gave poor results. Petroleum ether only partially precipitated the "gum" and precipitated some oil. Only a part of the resin in films containing resin and oxidized oil was extracted by chloroform. Esterification methods which include the use of petroleum ether gave poor results with spar varnish, due to precipitation of oil. With "short oil" varnish they gave good results for total oil and total resin, but the "gum" was only partially precipitated by petroleum ether, the soluble portion being separated from the oil by esterification. A method is proposed which includes esterification by the Twitchell or Wolff methods, ethyl ether being used as solvent after esterification. Since some resinous matter is weighed as fatty acids, a factor is used to correct the results. The greatest error in the average results by the proposed method was 2.2 per cent., expressed as percentage of the varnish.

DETERMINATION OF CARBON IN STEELS AND IRONS BY DIRECT COMBUSTION IN OXYGEN AT HIGH TEMPERATURES.†

By J. R. Cain and H. E. Cleaves.

[ABSTRACT.]

A METHOD has been devised for the determination of carbon in steels and irons by direct combustion in oxygen at 950° to 1100° C., finishing above 1450°, so that the oxides of iron are kept fused for several minutes, in order to give the best possible

* Technologic Paper No. 65.
† Technologic Paper No. 69.

chance for liberating all the carbon. This method was tested by analyzing various types of plain carbon and alloy steel standards of the Bureau and some of the pig-iron standards, and the results obtained for carbon in this way were in the mean about 0.01 per cent. carbon above the certificate averages.

THE TESTING OF HYDROMETERS.*

The circular contains specifications for hydrometers, and information and instructions concerning their test. The new edition is not essentially different from the last, only minor additions and corrections having been made.

An Immense Deposit of Magnesite in Southern Nevada. Anon. (*U. S. Geological Survey Press Bulletin*, No. 259, February, 1916.)—A massive deposit of magnesite of unusual character that has recently been brought to the attention of the United States Geological Survey promises to yield a large and readily available supply of this material. The deposit lies in Clark County, Nev., in the valley of Muddy River, one of the tributaries of Virgin River, a few miles above the town of St. Thomas. The material has been known for some time as kaolin, and successful experiments for utilizing it as a porcelain clay are reported to have been made, though they have not yet resulted in the exploitation of the deposit. The recognized outcrops have been located as mining claims, and some preliminary exploration and development work has been done. A side track on the St. Thomas branch of the San Pedro, Los Angeles and Salt Lake Railroad, about three miles northeast of the northernmost group of claims, offers a readily available railroad connection, and the station has been named Kaolin, from this deposit.

The so-called kaolin is stated by the Geological Survey to be in fact magnesite, a part of a regularly stratified series of sedimentary strata exposed by stream channels that cut across a low ridge at the upper edge of Muddy Valley. The deposit forms a chalky-looking bluff, dazzlingly white in the bright sunlight. The material is porcelain-white, fine grained, and massive, is remarkably free from foreign material, but is not so hard as the more typical magnesite, and crumbles more rapidly on exposure to the weather.

The length at the surface of the magnesite deposit seems to be a mile at least, and the purer part of the deposit consists of beds

* Circular of the Bureau of Standards No. 16. 4th edition, revised

aggregating at least 200 feet in thickness. Within the section of purer material there are a few bands of sandy matter, but these are minor in amount and could undoubtedly be avoided in mining. The new deposits are so large and so readily accessible that they may form a valuable source of magnesite.

The greater part of the California magnesite is used in the manufacture of wood-pulp paper on the Pacific coast. Magnesite is coming into use in the manufacture of cement for floors, for artificial marble and tile, and to a certain extent as a stucco for exterior finish. Carbon dioxide is manufactured from raw magnesite, and the use of finely-ground caustic calcined magnesite in fire-retarding paint is now one of its important applications. The larger buildings of the Panama-Pacific Exposition, as well as other buildings on the exposition grounds, were treated with a fireproofing and damp-proofing magnesia paint.

The Stored Energy of the Submarine. ANON. (*Scientific American*, vol. cxiv, No. 7, February 12, 1916.)—Although the idea of underwater attack dates back to the Revolutionary War, it was not until the storage battery was perfected that the submarine became a practical weapon of war. However formidable in attack it may be, it is a relatively frail craft whose only refuge is the sea, under whose cloak it may lurk in wait for the enemy, and in whose depths it may hide after it has hurled its bolt. It can live only by stealth, and so, in order to steal through the water without awakening a suspicion of its presence, it must be equipped with a propelling power that is noiseless and leaves no visible trace of its operation. The storage battery and the motor it energizes are almost ideally suited to the requirements of the submarine, for they are silent and practically heatless, leaving no trail of bubbles to betray the presence of the submerged vessel.

The battery for our large new submarines consists of two units of 60 cells each, and the space occupied by each unit is about 12 feet long by 12 feet wide by 50 inches high. The two units are usually separated by a bulkhead. A complete battery of two units will weigh between 60 and 70 tons and their capacity will be approximately 3000 ampère-hours.

In the earlier days of the submarine it was not realized that a special form of battery was required for this use. At first the batteries were of the open-type construction; that is, the individual cells had no covers. Now submarine batteries are carefully sealed so that the electrolyte can never spill and so that salt water cannot enter the cell and come into contact with the sulphuric acid of the electrolyte and produce chlorine gas. In the latest type of battery each individual cell is sealed. Unfortunately it is impossible to seal a storage battery absolutely, for both in charging and discharging it generates hydrogen and oxygen. These must be carried off and dissipated in the hold of the vessel.

NOTES FROM NELA RESEARCH LABORATORY.*

THE TRUE TEMPERATURE SCALE FOR TUNGSTEN AND ITS EMISSIVE POWERS AT INCANDESCENT TEMPERATURES.

By A. G. Worthing.

THE experimental part of the work here reported consisted in measuring the brightness of an incandescent, hollow, cylindrical, tungsten filament perforated with small holes and mounted in a large lamp bulb. Such determinations were first made for a hole and then for the adjacent surface. The ratio of the latter brightness to the former, when corrected for the difference in temperature between the interior and the surface and for the departure from blackness of the radiation from the interior due to the presence of the small hole and any lack of symmetry in the filament temperature distribution, gives the emissive power for the substance at the surface temperature. Because the radiation from tungsten deviates from Lambert's cosine law, the emissive power has in the present work been so limited as to refer only to that radiation which leaves the surface normally.

Black-body temperatures were obtained by comparing the observed brightness, with the aid of Wien's radiation formula, with that of a black body at the palladium point. The true temperature scale consists of the relation thus found between the black-body temperature of the filament surface and that of the adjacent hole; *i.e.*, the true temperature of the filament.

A linear relation was found between emissive powers and true temperatures for the region 1200° K. to 3200° K. such that the emissive powers for the two limiting temperatures were respectively 0.467 and 0.406. The uncertainty in these values should not be much over 1 per cent. The respective corresponding differences between the red ($\lambda = 0.666\mu$) black-body temperatures and the true temperatures are 33° and 375°.

Measurements were attempted on the tungsten arc much after the manner described by Langmuir. Due to large temperature gradients across the molten tungsten, no satisfactory determina-

* Communicated by the Director.

tions could be made of the emissive power. However, it was noticed, contrary to what was concluded by Langmuir, that the brightnesses of molten and of solid tungsten at the melting-point are nearly identical. Assuming the linear relation between emissive power and temperature for solid tungsten to continue up to the melting-point, it follows that this occurs at 3630° K. This corresponds to a red black-body temperature of 3140° K. and an emissive power of 0.390.

Though the results given above are believed to be dependable within reasonable uncertainties of measurement, further verification with other filaments will be attempted previous to the publication of the completed paper.

"COLOR TEMPERATURE" SCALES FOR TUNGSTEN AND CARBON.

By E. P. Hyde, F. E. Cady, and W. E. Forsythe.

By "color temperature" of a solid body radiating by virtue of its temperature is meant that temperature of a black body at which its radiation matches in color that of the solid body in question, provided the radiation from the latter is such that a color match may be obtained. If this is not possible, then the color temperature is that temperature of the black body at which the radiation from the latter has the same relative intensities of emission in two chosen wave-lengths as that from the solid body. It has been shown in previous papers by one of the authors and others that very approximate color matches may be obtained in the case of such substances as carbon, tantalum, tungsten, osmium, and platinum. Moreover, making a simple and very probable assumption, it was shown to follow that for the metals studied the color temperature gives an upper limit, just as the ordinary so-called black body temperature gives a lower limit to the true temperature of the radiating metal.

In the present investigation the color temperature of tungsten is accurately determined by comparison with an electrically-heated carbon tube furnace, and this color temperature scale is compared with the black-body temperature scale and with the true temperature scale of tungsten, as determined by Worthing. The relation is also established between the color temperature and the specific

output in lumens per watt radiated by the tungsten filament. It is found that the color temperature scale, which accurately and very readily defines the temperature of radiating tungsten, is very much closer to the true temperature scale than the so-called black-body scale which has been used generally in the past. Untreated carbon, as in the untreated carbon filament lamps, has also been studied, though with less precision, as the non-uniformity of filament temperature and the variations in radiating properties of different allotropic forms of carbon did not warrant a more accurate study. Moreover, for carbon, no true temperature values were determined, as a satisfactory scale of true temperatures was not available.

The principal results for tungsten are summarized in Table I, all necessary corrections for bulb absorption, etc., having been made.

The corresponding values for untreated carbon, with the exception of the values of true temperature, are given in Table II.

The following mean relations between the color temperature and the total radiation, measured as watts, with all necessary corrections, were determined:

For tungsten $E = AT_c^{4.93}$

For untreated carbon, $E = BT_c^{4.13}$

in which E is the total radiation and T_c is the color temperature, A and B being constants.

TABLE I.

Specific Output, Color, Black-body, and True Temperatures for a Tungsten Lamp.

Lumens per watt	Color temperature	Black-body temperature ($\lambda = 0.665\mu$)	True temperature
1	1763° K.	1627° K.	1729° K.
2	1917	1753	1875
3	2025	1840	1976
4	2109	1909	2056
5	2179	1967	2125
6	2237	2017	2184
7	2290	2062	2238
8	2338	2102	2286
*8.275	2350	2113	2299
9	2383	2140	2332
10	2425	2174	2373

* This value corresponds to 1.2 watts per mean horizontal candle, assuming a reduction factor of 0.79.

TABLE II.

Specific Output, Color, and Black-body Temperatures for a Carbon Lamp.

Lumens per watt	Color temperature	Black-body temperature ($\lambda = 0.665\mu$)
0.38	1672° K.	1647° K.
.55	1736	1707
.75	1795	1762
.98	1849	1815
1.25	1904	1866
1.56	1954	1913
1.90	2003	1959
2.28	2050	2002
2.42	2065	2017
2.69	2095	2045

THE CANDLE-POWER OF THE BLACK BODY AND THE MECHANICAL EQUIVALENT OF LIGHT.

By E. P. Hyde, F. E. Cady, and W. E. Forsythe.

THE candle-power of a vacuum carbon tube black body was measured for a temperature range from 1800° K. to 2600° K. Conditions were not as steady, and hence the accuracy was not as great at the higher temperatures as at the lower.

Diaphragms were located within the heater tube so as to make it as nearly black as possible. The limiting diaphragm was about 5 mm. for part of the work and 4 mm. for the remainder. These limiting diaphragms were so located that no radiation reached the photometer excepting from the central diaphragm within the furnace tube. The temperature of the carbon tube furnace was measured with an optical pyrometer which had been calibrated by direct comparison with a platinum-wound black body held at the temperature of melting palladium. Higher temperatures were measured by extrapolating by means of Wien's equation, using sectored disks.

When making the intensity measurement at any given temperature of the black body the comparison lamp was set at an approximate color match and the candle-power of this comparison lamp was subsequently measured in terms of carbon lamp standards from the Bureau of Standards. Check values of the candle-power were made at two low temperatures (1710° K. and 1820° K.) from a platinum-wound black body. These checked the values from the carbon tube furnace within the limit of error.

The results at the different temperatures are given in the table. While further experiments now under way may show changes, the results given are probably correct to within ten degrees through the range.

Having the candle-power of the black body at a definite temperature makes it possible to calculate the mechanical equivalent of light for the wave-length of greatest visibility (0.555μ.) If M represents the mechanical equivalent in lumens per watt, F the luminous flux per cm.^{2} for the black body expressed in lumens ($= 4\pi \times$ mean spherical candle-power), H_λ the visibility of radiation, and E_λ the distribution of energy in the black-body radiation for a particular temperature, we have $M\int_0^\infty H_\lambda E_\lambda d\lambda = F$. For H_λ the values obtained by Nutting, together with the values previously determined in this laboratory, were used. Determining E_λ by Wien's equation where $C_1 = 3.8 \times 10^{-12}$ $\frac{\text{watts}}{\text{cm.}^2}$, $C_2 = 1.4460$, M was determined for four different temperatures. The average of the results thus obtained is 760 lumens per watt as the mechanical equivalent of light for the wave-length of greatest visibility.

Brightness of a Black-body Furnace at Various Temperatures.

Temperature	Candles per mm.^{2}
1700° K.	0.053
1800	0.113
1900	0.244
2000	0.45
2100	0.80
2200	1.46
2300	2.48
2400	3.82
2500	6.0
2600	8.8

Practically Silent Railroad Wheels. ANON. (*Scientific American*, vol. cxiv, No. 7, February 12, 1916.)—Despite the number of attempts made in the past to produce a really silent wheel for railroads, no successful wheel of this type has been generally adopted by the railroad companies. In the course of long-continued tests there always cropped out disadvantages which the inventor had overlooked in the design of his wheel. At the present time, however, eastern railroad officials are greatly interested in the performances

of a new type of wheel which has been undergoing severe tests and subjected to nearly a year of actual service.

The new wheel consists of two distinct parts: a hub surrounded by a tread casting. These two members are separated by a space concentric with the periphery into which a cushion of rubber is inserted. Reëntrant curves at intervals are provided to prevent creeping. Among the advantages claimed by the inventor, and so far borne out by tests made in Portland, are the following: Several times the tire service of an ordinary cast-iron wheel; tires are easily removed and renewed; wear of the cushion proper is estimated at four years on average trolley service; steam railroad tests indicate its good influence on the rolling stock, rails, and switches; on city and interurban trolley lines the question of excessive noise is solved to the satisfaction of residents along the routes; greatly-improved riding qualities of the cars and greater comfort for the passengers.

A Hydraulic Analogy of the Wheatstone Bridge. R. S. WHIPPLE. (*Proceedings of The Physical Society of London*, vol. xxviii, part i, December 15, 1915.)—The analogy of the flow of water along pipes is frequently used when teaching Ohm's law, but the author does not know of a published description of a simple model. About 18 years ago Professor Callendar showed a model of a Wheatstone bridge in which the arms of the bridge consisted of small capillary tubes through which a stream of gas or air could be passed. The galvanometer, or differential pressure indicator, as it was in this case, consisted of a mica vane pivoted in such a manner that it was deflected whenever the pneumatic pressure became greater on one side of the vane than on the other. By means of taps and tubes of various lengths Professor Callendar was able to show the effect of increasing or diminishing the length of pipe through which the gas passed. The objection to the pneumatic model from the teacher's point of view is that the pressure indicator is difficult to make, and that all the taps require good workmanship. In the model shown, glass and India-rubber tubing with some glass taps are all that are required. The solution used is water colored with ink, and this is allowed to flow slowly through the bridge circuit.

The galvanometer or detector is simply a large air bubble in a horizontal glass tube placed across the bridge arms. A tap is placed in the tube for adjusting the size of the bubble. When the capillary resistance of the tubing on each side of the bridge is equal, the bubble is stationary in the centre of the tube. As soon as the balance of the bridge is disturbed by either partially closing a tap or by introducing another length of tubing by the opening of a tap, the want of balance is shown immediately by the movement of the air bubble. Balance is restored by introducing or diminishing the resistance in the opposite arm of the bridge, and the bubble at once takes up its null position.

NOTES FROM THE RESEARCH LABORATORY, GENERAL ELECTRIC COMPANY.*

RÖNTGEN-RAY SPECTRA.

By A. W. Hull.[1]

THIS article is a first report of work upon the accurate measurement of the quality and intensity of X-rays from a standard and exactly reproducible X-ray tube.

A Coolidge tube is excited by a voltage of 100,000, boosted from the 150-volt, 2000-cycle alternating current of the mains by a transformer, and rectified by kenotrons. Oscillations are smoothed out by inductance and capacity until the voltage variations are less than a per cent. for 5 kilowatts and are still smaller for loads below 5 kilowatts.

The spectrometer is of the usual form, with a crystal of rock salt or Iceland spar substituted for the prism, and an ionization chamber in place of a photometer.

Wave-length and intensity values for the X-ray spectra from a tungsten target at five different voltages from 20,000 to 40,000 are plotted, and show a very rapid decrease in wave-length, with rise in voltage, and at the same time an increase in intensity for all wave-lengths. Hence a penetrating ray free from soft radiations can be obtained only by using a filter exhibiting selective absorption for the latter. Measurements of the spectrum at 70,000 volts with and without a filter of 3 mm. of aluminum indicate that the intensity of the soft rays has been reduced much more than that of the penetrating, but there is still a great deal of the former left. Use of still heavier filters to further reduce the intensity of soft rays would also cut down the intensity of the penetrating rays to a small fraction, but with a very powerful tube, such as in process of development, there may yet be left sufficient for practical work. It is also hoped that by use of some special target material giving a powerful radiation of a particular wave-length it may be possible to obtain still purer "monochromate"

* Communicated by the Director.

[1] *American Journal of Röntgenology*, 2, 893–9, December, 1915.

rays of high penetration. It is the wave-length that determines penetration, therapeutic action, and all other effects, and, with rays having the same spectrum, the only variable is milliampère-minutes.

Any spectrum obtained with constant voltage may be duplicated with fluctuating voltage by using a definite but different voltage and current, but the conversion factors must be known and will be large for machines differing greatly in wave-form.

The principles upon which the work is based, the operation of the spectrometer, and the method of obtaining constant voltage are explained in detail, with diagrams, curves, and oscillograms.

MAXIMUM FREQUENCY OF X-RAYS AT CONSTANT VOLTAGES BETWEEN 30,000 AND 100,000.

By A. W. Hull.[1]

MEASUREMENTS taken from curves of the energy distribution in the X-ray spectra at constant potentials determined with an accuracy of 3 or 4 per cent. by means of the spectrometer show that the maximum frequencies for voltages up to 100,000 are given accurately by the quantum relation; that is, they are proportional to the voltage. There is no tendency for the frequency to fall off at the higher voltages, such as Rutherford reported from work by the absorption method, and no indication that such falling off will occur at still higher voltages than those studied. At 95×10^3 volts the maximum frequency observed was 22.8×10^8.

NEGATIVE RESISTANCE.

By A. W. Hull.[2]

APPLICATION of the principles of electron emission in high vacuum has produced a device having all the characteristics of a true negative resistance. It consists of a hot filament cathode and plate anode, with an interposed perforated plate, or grid, maintained at a constant potential higher than the plate. This grid carries away the secondary electrons produced by bombardment

[1] *Physical Review*, 7, 156–8, January, 1916.
[2] *Physical Review*, 7, 141–3, January, 1916.

of the plate. As the velocity of the primary electrons from the filament increases, with increase of potential gradient from filament to plate, the secondary emission from the plate increases, slowly at first and then more rapidly, finally exceeding the primary when the net result at sufficiently high voltage is a loss of electricity from the plate. Consequently the current to the plate with rising voltage increases at first slowly up to a certain value, and then falls off rapidly, just as would occur with a negative resistance in circuit. This phenomenon is completely reversible, has no appreciable lag, and is aperiodic.

Typical of the many scientific applications of this apparatus is its use connected in series with a positive ohmic resistance, when it acts as an extremely sensitive amplifier of voltage changes across the terminals of the combination. Preliminary tests have given an amplification of 100-fold, and there should be no difficulty in going to 1000- or 10,000-fold.

SUMMARY OF PHYSICAL INVESTIGATION WORK IN PROGRESS ON (X-RAY) TUBES AND ACCESSORIES.

By W. D. Coolidge.[1]

THIS article is an illustrated discussion of the objects, progress, and outlook of some of the X-ray researches being prosecuted in the Research Laboratory. The following points are considered in detail:

Target design for sharp definition, requiring uniform energy distribution and cooling of the focal spot. Materials, water-cooling, constant current excitation, rotation, focussing of cathode rays.

Hooded target to cut out secondary radiations.

Reduction of size of bulb to 4 inches at least.

Tipless bulb.

High potential tube with hooded and water-cooled target. Current supply and voltage regulation. Transformer requirements.

Exact control of filament temperature.

Measurement of tube voltage.

[1] *American Journal of Röntgenology*, 2, 881–92, December, 1915.

HEAT CONDUCTIVITY OF TUNGSTEN AT HIGH TEMPERATURES AND THE WIEDEMANN-FRANZ-LORENZ RELATION.

By Irving Langmuir.[1]

CALCULATIONS based upon the previously-measured [2] resistance and power radiation of a tungsten filament between 600° and 2800° K. have led to the development of a differential equation to express the temperature distribution along a filament in the neighborhood of a cooling junction, from which values of the ratio of the temperature at the cooling junction to that at a point so far removed as to be unaffected by the junction can be calculated with any desired accuracy of approximation.

Recalculations from Worthing's data on the heat conductivity of tungsten at high temperatures [3] have shown that his experimental results are quite consistent with the assumption that the heat conductivity is practically independent of temperature. The value at 2410° K. from these data is 1.14 watts per centimetre per degree.

Allowing a temperature coefficient, as suggested by the work of Jaeger and Dieselhorst, tungsten fits in with the Wiedemann-Franz-Lorenz relation as well as do most other pure metals.

RADIATION FROM TUNGSTEN FILAMENTS AND THE MECHANICAL EQUIVALENT OF LIGHT.

By Irving Langmuir.[4]

FROM careful measurements on fifteen special lamps, of volts, ampères, candle-power, and temperature, corrected for the cooling effect of leeds, and of length and diameter of filaments, the following quantities were calculated for some 19 different temperatures between 273° and 3540° K.:

1. Specific resistance.
2. Resistance exponent, $n_R = d \log R / d \log T$.

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[1] *Physical Review*, 7, 151–2, January, 1916.
[2] *Ibid.*, 7, 152–4, January, 1916.
[3] *Ibid.*, 4, 538 (1914).
[4] *Ibid.*, 7, 152–4, January, 1916.

3. Watts radiated per unit surface.

4. Watts exponent, $n_w = d \log W / d \log T$ where W = watts radiated at 0° K.

5. Total emissivity. (Watts radiated as fraction of total radiation from a black body at the same temperature.)

6. Intrinsic brilliancy per square centimetre of projected area.

7. Color expressed as temperature of a black body which emits light of the same color.

The mechanical equivalent of light, using Nutting's visibility data and taking as constants of the Planck equation

$$C_1 = 3.72 \times 10^{-21} \text{ watts}$$
$$C_2 = 1.4392$$

was found to be 0.00121 watt per lumen, compared with Nutting's value of 0.00120, and that of Ives, Coblentz, and Kingsbury, 0.00162. If the last value is correct, either the emissivity of tungsten for $\lambda = 0.55$ should be 0.67 (instead of 0.50) or the melting-point must be at least 3750° K., both of which suppositions are wholly inconsistent with the observations.

The methods of measurement are stated and a table of the numerical results given.

The Production of Ammonia from Cyanamid. W. S. LANDIS. (*Journal of Industrial and Engineering Chemistry*, vol. 8, No. 2, February, 1916).—The large number of installations operating with perfect success in various parts of the world for a number of years have demonstrated the commercial possibility of making ammonia from lime nitrogen. The plant, in its present highly-developed state, is extremely certain in its action and simple to operate. The efficiency obtained in the transformation of the nitrogen in lime nitrogen into ammonia gas is upward of 98 per cent. The consumption of reagents is remarkably small, and they are cheap and easy to obtain in all parts of the world.

The quality of the ammonia produced by this process is not surpassed by any in the United States. It is chemically pure as produced, and requires no further costly and tedious purification to render it available for the highest grade chemical products or for the production of the liquefied anhydrous product. The actual cost of production of this high-grade pure ammonia on a considerable scale, which enables one to take advantage of the lower price at which lime nitrogen is offered, brings high-grade cyanamid-ammonia into the market almost as cheaply as the most impure forms already found there, and very much cheaper than it is possible to obtain an equal quality of ammonia from gas-house liquor, the coke ovens, etc.

An Investigation on the Transmission, Reflection, and Absorption of Sound by Different Materials. F. R. WATSON. (*The Physical Review*, vol. vii, No. 1, January, 1916.)—The apparatus employed in the experiments on the transmission of sound consisted of an adjustable whistle for a sound source, mounted at the focus of a parabolic reflector with a focal length of nine inches and an aperture of five feet. This was placed in front of an open doorway, so that the sound, which proceeded in a large bundle from the reflector, could pass through the doorway into another room. The receiver of sound, a Rayleigh resonator, was mounted in the other room in the path of the sound symmetrically opposite the reflector and doorway, and measured the intensity of the transmitted sound.

The resonator used is a modification of Rayleigh's original design. It consists of a horizontal brass tube closed at one end by an adjustable piston. A mica disk is suspended by a quartz fibre at an angle of 45° with the axis of the tube. When the sound of the whistle reached the resonator, it set up a back-and-forth surging of the air in the resonator and caused the mica disk, which was placed at the loop, to rotate. This action is in accordance with the general principle that any flat object in a current of air tends to set itself at right angles to the current. The amount of rotation was measured by means of a lamp and scale in connection with a mirror which was attached to the suspended system above the mica disk. Measurements were taken, first, through the open doorway, then with one panel of material placed over the doorway, then two panels, and, finally, three panels, the deflection of the resonator being noted for each case.

The results show that ½-inch hairfelt stops less sound than other materials, one layer stopping only 43 per cent. Next comes ¼-inch cork board, which stops 80 per cent. for one layer and 90.5 per cent. and 92.6 per cent. for two and three layers respectively. This is followed by ¾-inch paper-covered hairfelt, ¾-inch flaxboard, and, finally, ¼-inch pressed fibre, one layer of which stops practically all the sound.

The transmission of sound of constant pitch depends on at least three qualities of the transmitting material: its porosity, density, and elasticity. Porous bodies transmit sound in much the same proportion that they transmit air. This is why the hairfelt transmits more sound than the other samples. Density also plays a part. Two materials stop sound in proportion to their densities, other conditions being equal. Thus the pressed fibre stops more sound than the same thickness of cork, because it is heavier. Finally, an elastic body may transmit sound if it happens to be in tune with the source in sound so as to vibrate in unison with it. When the pitch of the sound varies, porous walls and elastic walls reflect high-pitched sounds in greater degree than low-pitched ones.

THE FRANKLIN INSTITUTE

(Proceedings of the Stated Meeting held Wednesday, February 16, 1916.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, February 16, 1916.

PRESIDENT DR. WALTON CLARK *in the Chair.*

Additions to membership since last report, 7.

Mr. Charles E. Bonine, chairman of the Committee on Science and the Arts, reported the condition of the work of the committee.

The standing committees for the year 1916–17 were announced.

G. E. deSchweinitz, Esq., M.D., LL.D., of Philadelphia, presented the paper of the evening, entitled "Drug and Occupational Amblyopias."

Consideration was given to the deleterious effects on the visual apparatus caused by the abuse of tobacco and alcohol, and particular reference was made to the dangers of wood-alcohol as it is employed in the various trades and as it is abused when employed as an adulterant and to take the place of grain-alcohol, particularly in cheap grades of essence of peppermint, bay rum, etc. The dangers to the ocular apparatus of those who work in lead, bisulphide of carbon, nitrobenzol, and dinitrobenzol were described, as well as the visual disturbances caused by the ingestion of large doses of quinine, salicylic acid, and certain arsenic preparations, notably atoxyl. The lecture was illustrated by numerous lantern slides, showing the lesions in the ocular apparatus and charts of the visual field.

After a brief discussion the thanks of the meeting were extended to Dr. deSchweinitz.

Adjourned.

R. B. OWENS,
Secretary.

STANDING COMMITTEES, 1916.

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MEETINGS.

Gellert Alleman,
Charles Baskerville,
G. H. Clamer,
George R. Henderson,
Herbert E. Ives,
A. E. Kennelly,
Edwin F. Northrup,
M. M. Price,
James S. Rogers,
George D. Rosengarten.

MUSEUMS.

Emile Berliner,
Charles F. Brush,
Arthur L. Church,
Henry F. Colvin,
Charles Day,
George A. Hoadley,
Henry Howson,
A. E. Outerbridge, Jr.,
Coleman Sellers, Jr.,
Thomas Spencer.

COMMITTEE ON SCIENCE AND THE ARTS.

(*Abstract of Proceedings of the Stated Meeting held Wednesday, February 2, 1916.*)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, February 2, 1916.

MR. G. H. CLAMER *in the Chair.*

Mr. C. E. Bonine was unanimously elected Chairman for the year 1916.

The following reports were presented for first reading:

No. 2654.—Circle Drawing Attachment for Microscopes.

No. 2655.—Prepayment Gas Meter.

The following reports were presented for final action:

No. 2626.—Dorr's Hydrometallurgical Apparatus: the Dorr Classifier, the Dorr Thickener, and the Dorr Agitator. John V. N. Dorr recommended to the City of Philadelphia for the John Scott Legacy Medal and Premium.

No. 2634.—Cement-Gun. Carl E. Akeley recommended to the City of Philadelphia for the John Scott Legacy Medal and Premium.

R. B. OWENS,
Secretary.

SECTIONS.

Section of Physics and Chemistry.—A meeting of the Section was held in the Hall of the Institute on Thursday, February 10, 1916, at 8 o'clock P.M., with Dr. Robert H. Bradbury in the chair. The minutes of the previous meeting were approved.

Charles Baskerville, Ph.D., F.C.S., Professor of Chemistry, College of the City of New York, presented a paper on "Refining of Animal and Vegetable Oils." Dr. Baskerville described the process at present in use for refining vegetable oils by neutralizing the free fatty acids in the crude oil, usually by agitating the oil with an aqueous solution of an alkali, and then heating the mixtures during agitation until the oil "breaks." The mass is then allowed to stand until the "foots" settle and the oil drawn off by means of a siphon. He then demonstrated a new process for increasing the speed of refining and also for increasing the quantity of refined oil and at the same time reducing to a minimum the amount of oil entrained in the "foots." The subject was illustrated by several experiments.

After a brief discussion, a vote of thanks was extended to the lecturer and the meeting adjourned.

T. R. PARRISH,
Acting Secretary.

Mechanical and Engineering Section.—A joint meeting of the Section and the American Society of Mechanical Engineers was held in the Hall of the Institute on Thursday, February 3, 1916, at 8 P.M.

Mr. Charles Day and Professor Fernald presided jointly.

Mr. Day introduced Arthur M. Greene, Professor of Mechanical Engineering, Rensselaer Polytechnic Institute, Troy, N. Y., who presented a paper on "The Development of the Pumping Engine."

The lecturer described the earliest devices for raising water, and traced the development of pumping apparatus from ancient times to the present day. Consideration was given to the inventions and improvements of Hero, Savery, Newcomen, Watt, Bull, Worthington, Reynolds, Gaskill, d'Auria, and others, and the special contributions of each to the perfection of the apparatus were pointed out. The modern requirements of a pumping engine were outlined and recent large installations were described. The subject was illustrated by one hundred lantern slides.

After a brief discussion, a vote of thanks was extended to Professor Greene.

Adjourned.

T. R. PARRISH,
Acting Secretary.

MEMBERSHIP NOTES.

(Stated Meeting, Board of Managers, February 9, 1916.)

ELECTIONS TO MEMBERSHIP.

RESIDENT.

MR. JOHN B. DECOURSEY, The Gladstone, Eleventh and Pine Streets, Philadelphia, Pa.

MR. GEORGE A. DUNNING, refrigerating engineer, Standard Ice Manufacturing Company, Twenty-seventh and South Streets, Philadelphia, Pa.

MR. JAMES ELVERSON, publisher, *The Philadelphia Inquirer*, Philadelphia, Pa.

MR. FRANK H. SAUER, draftsman, 1307 Atlantic Avenue, Camden, N. J.

NON-RESIDENT.

MR. A. STUART BALDWIN, chief engineer, Illinois Central Railroad Company, Chicago, Ill.

MR. E. W. Lloyd, general contract agent, Commonwealth Edison Company, Edison Building, Chicago, Ill.

MR. S. S. RIEGEL, mechanical engineer, The Delaware, Lackawanna and Western Railroad Company, Scranton, Pa.

CHANGES OF ADDRESS.

MR. CHARLES O. BOND, 7008 Greene Street, Mt. Airy, Philadelphia, Pa.

MR. JUSTICE C. CORNELIUS, 712 Ferry Street, Easton, Pa.

DR. ERNST FAHRIG, 720 Metropolitan Avenue, Atlantic City, N. J.

MR. JOHN B. RUMBOUGH, P. O. Box 2, Asheville, N. C.

MR. DAVID H. WILSON, JR., Wilson Welder and Metals Company, Vanderbilt Avenue and Forty-fifth Street, New York City, N. Y.

NECROLOGY.

Mr. Coleman L. Nicholson, 117 Argyle Road, Ardmore, Pa.

LIBRARY NOTES.

PURCHASES.

American Annual of Photography, vol. 30. 1916.

American Society of Mechanical Engineers.—History, 1880–1915, by F. R. Hutton. 1915.

FINDLAY, ALEX.—Practical Physical Chemistry. 1914.

International Master Boiler Makers' Association.—Proceedings, volumes 1 to 9. 1907 to 1915.

Jahrbuch der Chemie.—Jahrgang 24. 1914.

JOHNSON, CHARLES M.—Rapid Methods for the Chemical Analysis of Special Steels. 1914.

LE BAS, GERVAISE.—Molecular Volumes of Liquid Chemical Compounds. 1915.

MACH, ERNST.—The Science of Mechanics. 1907, Supplement to 3d English Edition. 1915.

MARTIN, GEOFFREY.—Chlorine and Chlorine Products. 1915.

MARTIN, GEOFFREY, and BARBOUR, W.—Industrial Nitrogen Compounds and Explosives. 1915.

MARTIN, GEOFFREY, and DANCASTER, E. A.—The Halogens and Their Allies. 1915.

METCALF, L., and EDDY, H. P.—American Sewerage Practice, vol. 3. 1915.

MEYER, KIRSTINE.—Die Enwickelung des Temperaturbegriffs im laufe der Zeiten. 1913.

NICKEL, FRANK F.—Direct-acting Steam Pumps. 1915.

PEARSON, HENRY C.—Rubber Machinery. 1915.

PIRSSON, L. V., and SCHUCHERT, C.—Text-book of Geology. 1915.

POINCARÉ, HENRI.—Science and Method. No date.

SHARP, ARCHIBALD.—Balancing of Engines—Steam, Gas, and Petrol. 1907.

Tables annuelles de constantes et données numériques de chemie, volumes 2 and 3. 1911, 1912.

WASHBURN, E. W.—Introduction to the Principles of Physical Chemistry. 1915.

WELLTON, O. G.—Problems Relating to Steel Tubes When Used as Liquid Conductors. 1915.

GIFTS.

American Institute of Electrical Engineers. Year Book. New York, 1916. (From the Institute.)

American Institute of Mining Engineers, Transactions, vol. ii, 1915. New York, 1916. (From the Institute.)

American Railway Master Mechanics' Association, Proceedings, vol. xlviii. Chicago, 1915. (From the Association.)

American Society of Civil Engineers, Transactions, vol. lxxix. New York, 1915. (From the Society.)

Bauer, O., and E. Deiss, The Sampling and Chemical Analysis of Iron and Steel. New York, 1915. (From Dr. Andrew A. Blair.)

Boston Transit Commission, Twenty-first Annual Report. Boston, 1915. (From the Commission.)

Canada Department of Public Works, Report. Ottawa, 1915. (From the Department.)

Canal Record, vol. 8. Balboa Heights, Canal Zone, 1915. (From the Panama Canal.)

Carnegie Institution of Washington, Year Book, No. 14. Washington, 1915. (From the Institution.)

Carnegie Steel Company, Steel Sheet Piling, Tables and Data on the Properties and Uses of Sections, 10th Edition. Pittsburgh, no date. (From the Company.)

Case School of Applied Science, Catalogue, 1915–1916. Cleveland, no date. (From the School.)

Chambers Brothers and Company, Catalogue and Price List of Book-folding Machines. Philadelphia, 1874. (From Mr. J. P. Manypenny.)

Dixon, Joseph, Crucible Company, Graphite. Jersey City, 1915. (From the Company.)

Harvard University, Catalogue 1915–1916. Cambridge, 1916. (From the University.)

Hindley Gear Company, Catalogue No. 5 of Worm Gears and Spirals. Philadelphia, no date. (From the Company.)

International Railway General Foremen's Association, Proceedings, Eleventh Annual Meeting. Winona, Minn., 1915. (From the Association.)

Institution of Civil Engineers, Minutes of Proceedings, vol. cc. London, 1915. (From the Institution.)

Library of Congress, Report of the Librarian. Washington, 1915. (From the Library.)

Master Car Builders' Association, vol. 49, parts i and ii. Chicago, 1915. (From the Association.)

Michigan Gas Association, Proceedings, Twenty-fourth Annual Meeting. No place, 1915. (From the Association.)

Miller, Herman P., and W. Harry Baker, Smull's Legislative Hand Book and Manual of the State of Pennsylvania. Harrisburg, 1915. (From the State Librarian.)

New York Board of Water Supply, Contract 128, Information for Bidders, Forms of Proposal, Contract, Bonds, Certificates, Specifications and Drawings for the Construction of Two Superstructures for Hill View Uptake and Downtake Chambers in the City of Yonkers, Westchester County, New York. New York, 1915. (From the Board.)

New York State Public Service Commission for the First District, Proceedings, vol. x. New York, 1915. (From the Commission.)

Princeton University, Official Register, 1915–1916. Princeton, 1915. (From the University.)

Royal Academy of Sciences, Jaarboek, 1914, Proceedings of the Section of Sciences, vol. xvii, parts 1 and 2. Amsterdam, 1914, 1915. (From the Academy.)

Royal Society of New South Wales, Journal and Proceedings, vol. xlix, part i. Sydney, 1915. (From the Society.)

Staffordshire Iron and Steel Institute, Proceedings, vol. xxx. Stourbridge, 1915. (From the Institute.)

U. S. Army, Annual Report of the Chief of Engineers, parts 1, 2, 3. Washington, 1915. (From the Chief of Engineers.)

U. S. Coast and Geodetic Survey, Serial No. 19, Results of Observations Made at the United States Coast and Geodetic Survey Magnetic Observatory at Cheltenham, Maryland, 1913 and 1914. Washington, 1915. (From the Survey.)

U. S. War Department, Fifteenth Annual Report of the Bureau of Civil Service to the Governor-General of the Philippine Islands, 1914. Manila, 1915. (From the Department.)

U. S. Naval Observatory, Publications, Second Series, vol. ix, part ii, The American Ephemeris and Nautical Almanac for the Year 1918. Washington, 1915. (From the Observatory.)

University of Cincinnati, Annual Catalogue, 1915–1916. Cincinnati, no date. (From the University.)

Washington University, Fifty-ninth Annual Catalogue. St. Louis, 1915. (From the University.)

Western Australia Geological Survey: Bulletin No. 58, Palæontological Contributions to the Geology of Western Australia. Bulletin No. 62, Notes on the Geology and Mining at Sanstone and Hancock's, East Murchison Goldfield. Bulletin No. 65, The Reputed Petroliferous Area of the Warren River District. Perth, 1914 and 1915. (From the Survey.)

Wisconsin Geological and Natural History Survey, Bulletin xlii, The Geography of the Fox-Winnebago Valley. Madison, 1915. (From the Survey.)

BOOK NOTICES.

THE METALLOGRAPHY AND HEAT-TREATMENT OF IRON AND STEEL, by Albert Sauveur, Professor of Metallurgy and Metallography in Harvard University and The Massachusetts Institute of Technology. Second edition. Cambridge, Sauveur and Boylston, 1916. 504 pages, 438 illustrations, 8vo. Price, $6.

This is a new edition, revised and enlarged, of Professor Sauveur's "Metallography of Iron and Steel," published in 1912, a comprehensive review of which appeared in the JOURNAL OF THE FRANKLIN INSTITUTE, February, 1913. The author states that 50 pages of new matter and nearly 100 new illustrations have been added in this revision.

Careful comparison of the first and second editions shows that practically the same arrangement of matter and illustrations has been retained, substituting the word "Chapter" for "Lesson" in each subdivision and transferring the instructions regarding "Manipulation and Apparatus" from the Appendix in the first edition to Chapters II and III in the new edition.

For those who do not already possess the first edition this new edition will prove invaluable not only to students of metallurgy but also to practical workers in the field which it covers so fully.

There has been an unexpectedly great enlargement of need for such a thoroughly up-to-date book in this country since the first edition appeared, shortly before the outbreak of the European war, for very many establishments have obtained large contracts for metallurgical products requiring most careful and accurate heat-treatment.

A new edition of this classic is therefore timely.

ALEX. E. OUTERBRIDGE, JR.

A HANDBOOK OF COLLOID-CHEMISTRY: THE RECOGNITION OF COLLOIDS, THE THEORY OF COLLOIDS, AND THEIR CHEMICO-PHYSICAL PROPERTIES, by Wolfgang Ostwald. First English edition, translated from the third German edition by Martin H. Fischer, assisted by Ralph E. Osper and Louis Berman. Philadelphia, P. Blakiston's Son & Co., 1915. 266 pages, illustrations, 8vo. Price, $3.

It is a question of literary taste whether the German word "Handbuch" may not be better rendered by the word "Manual," or even whether the simple title "Colloid-Chemistry" would not have been enough. However, the

reviewer is not concerned with these details, but with the merits of the book and scope of it. It is, indeed, hardly necessary to criticise. One may be sure that the volume will be found to be a comprehensive and authoritative exposition of the field to which it is devoted, and the principal points to which examination of the English edition should be directed are the correctness of the translation and the adherence to the English idiom. The work seems entirely satisfactory in these respects. There is a gratifying lack of awkward phrases that are so often found in works translated from the German.

A summary of the tables of contents will give an idea of the scope of the work. Under the head of General Colloid-Chemistry are discussed: Relations between physical state and general properties; general energetics of the dispersoids; distribution of the colloid-state and the concept of colloid-chemistry. Under the head of Special Colloid-Chemistry are discussed: Relations of volume and mass in colloids; movement in colloid systems and its results.

Dr. Fischer, in his preface, refers to the fact that the problems of colloid-chemistry are nowadays more to the fore than those of the crystalloids. This is probably due to the fact that the crystalloid condition is essentially one of rest, while the colloid condition is one of action. He also expresses, not unnaturally, astonishment at the fact that seven years and three large German editions of this work were required before it appeared in the language of Thomas Graham and the brilliant group of modern English-speaking colloidists.

The book has a portrait of Thomas Graham as a frontispiece, and is well printed. It is scarcely necessary to say that it will at once take front rank among the works available in English to the student of this important, complex, and rapidly-growing field of science.

HENRY LEFFMANN.

AN INTRODUCTION TO THE PHYSICS AND CHEMISTRY OF COLLOIDS, by Emil Hatschek. Philadelphia, P. Blakiston's Son & Company, 1916, 102 pages. Second edition. 17 illustrations, 12mo. Price, $1.

This is an excellent summary of the facts and theories concerning colloids and can be read almost at one sitting (not "setting," as the author gives the word on page 17). In the preface to the first edition, which is reprinted in the present issue, it is stated that the work is essentially a republication of articles that appeared in the *Chemical Trade Journal*, based on lectures delivered at the Sir John Cass Technical Institute, to an audience composed of students in many departments of chemistry and of widely different degrees of preparation, hence the necessity for a distinctly elementary treatment of the topics. In the present issue the work has been increased by an appendix on technic.

The book is well printed, and a perusal of it will give much important information to that numerous class of chemists who began their studies in the third quarter of the last century, when Graham's work was new and "Chemical Physics" was a mere side-issue in science. HENRY LEFFMANN.

PUBLICATIONS RECEIVED.

Organic Chemistry; or, Chemistry of the Carbon Compounds, by Victor von Richter. Edited by Prof. R. Anschütz and Prof. G. Schroetter. Vol. i, Chemistry of the Aliphatic Series. Newly translated and revised from the German edition (after Prof. Edgar F. Smith's third American edition), by Percy E. Spielmann, Ph.D., B.Sc., F.I.C., A.R.C.Sc. 719 pages, illustrations, 8vo. Philadelphia, P. Blakiston's Son & Co., 1916. Price, in cloth, $5.

Catalysis and its Industrial Applications, by E. Jobling, A.R.C.Sc., B.Sc., F.C.S. Reprinted from *The Chemical World*. 120 pages, illustrations, 12mo. Philadelphia, P. Blakiston's Son & Co., 1916. Price, in cloth, $1.

An Introduction to the Physics and Chemistry of Colloids, by Emil Hatschek. Second edition, 107 pages, illustrations, 12mo. Philadelphia, P. Blakiston's Son & Co., 1916. Price, in cloth, $1.

Annuaire pour l'an 1916 publie par le Bureau des Longitudes. Avec des Notices Scientifiques. 657 pages, 24mo. Paris, Gauthiers-Villars, no date. Price, in paper, 1 franc 50c.

U. S. Bureau of Standards, Technologic Paper No. 53, An Investigation of Fusible Tin Boiler Plugs, by George K. Burgess, Physicist, and Paul D. Merica, Assistant Physicist. 37 pages, illustrations, 8vo. Washington, Government Printing Office, 1915.

U. S. Bureau of Mines, Technical Paper 108, Shot Firing in Coal Mines by Electricity Controlled from the Outside, by H. H. Clark, N. V. Breth, and C. M. Means. 36 pages, 8vo. Washington, Government Printing Office, 1915.

The Periodic System and the Properties of the Elements. W. D. HARKINS and R. E. HALL. (*The Journal of the American Chemical Society*, vol. xxxviii, No. 2, February, 1916.)—In this paper a periodic table has been presented which shows graphically the relations between the main and the sub-groups of elements. The main defect of the periodic tables which have been designed formerly is that they do not show these relations correctly. The table arranges the elements in the exact order of their atomic numbers, and gives no blanks for unknown elements which do not correspond to atomic numbers as determined by Moseley's work on the X-ray spectroscopy of the elements. It also plots the elements according to their atomic weights, so the isotopic forms of an element may be shown graphically on the table, and the alpha and beta decompositions of the radio-active elements may also be plainly depicted. Both the zero and the eighth groups fit naturally into the system.

The table may be best represented as a helix in space, but may be shown as a spiral in a plane. The space form is represented by its vertical projection on a plane, but drawn with line perspective so that it may be easily visualized.

CURRENT TOPICS.

Development of the Incandescent Lamp. From "Light and Illumination," C. P. STEINMETZ. (*Journal of the Western Society of Engineers*, vol. xx, No. 9, November, 1915.)—All the advance made in illuminating engineering has been made by utilizing higher and higher temperatures. Attempts at producing light by the electric current were made by heating wire conductors to a high temperature, and the first attempt at an incandescent lamp was with a platinum wire; but platinum melts at about 1760° C., and the efficiency of light production by this means was very low. Then Edison discovered that a wire of carbon—a carbon filament—could be used in the place of platinum. Carbon does not melt or boil until a temperature of about 4000° C. is reached. Consequently it should withstand a much higher temperature in an incandescent lamp than platinum. The old carbon filament lamps were run at about 1800° C., somewhat above the melting-point of platinum, and thus with higher efficiency and no danger of melting. About 45 watts of electrical energy were required per candle-power.

Higher temperature and correspondingly better efficiency were limited, not by the melting or the boiling of the filament, but by another limitation—evaporation. The carbon filament, much below its melting- and boiling-point, slowly evaporated, the carbon vapor being deposited on the lamp bulb. With continuous evaporation the filament became thinner; thereby the temperature lowered and the light became less. The deposited carbon vapor also obstructed the light. The operating temperature of the old carbon filament lamp is therefore limited to a value where the rate of evaporation does not unduly reduce the light production within a reasonable time of, say, 500 hours or so.

The material obtained by carbonizing the bamboo fibre employed in incandescent lamps evaporates rather rapidly, but carbon deposited from gasoline at high temperature does not evaporate so easily and can be used at higher temperatures. A higher efficiency was therefore obtained by depositing a shell of carbon from gasoline vapor upon the carbon filament produced from fibre.

The carbon filament of the old incandescent lamp evaporated, although it was operated at a temperature much below the boiling- and melting-point. Tungsten, on the other hand, can be run nearly at the temperature of the melting-point with very little evaporation. Osmium proved very efficient as an illuminant in a lamp, but is too rare to be generally used. Tantalum gave good results, having a higher resistance than carbon, but it has been superseded by tungsten,

because the melting-point of the latter is much higher and is now used in all lamps having metallic filaments. The so-called "Mazda" is a tungsten lamp and requires one watt per candle, while the carbon lamp requires three watts per candle.

In the carbon and tungsten lamps a vacuum has been used. Naturally the lamp having a carbon filament must at least be exhausted of air to prevent its combustion, but that is not the fundamental reason for the vacuum, because the lamp bulb might be filled with a gas in which carbon will not burn, such as nitrogen, hydrogen, or argon. But to maintain the carbon filament in such a gas at the temperature it would have in a vacuum would require much more energy. The use of a vacuum, however, is disadvantageous, because it facilitates evaporation, and thus sets a lower and less efficient limit to the temperature to which in practice the filament should be raised, even though far below the melting- or boiling-point.

Assume the evaporation in a vacuum to be such as to limit the life of the lamp to 1000 hours at the temperature produced by 100 watts, then with nitrogen at atmospheric pressure we could use, say, 200 watts with the same rate of evaporation and blackening. But this would raise the temperature, so that, while 100 watts will give 200 candles, 200 watts would give 600 candles, were it not for the heat carried away by the nitrogen from the filament. Consequently an additional 100 watts must be supplied to make up for this loss and raise the temperature sufficiently to give the 600 candles. In this way the candle-power of the lamp has been increased from 200 candles with an expenditure of 100 watts to 600 candles for 300 watts with the same evaporation, blackening, and life, which means an increase in efficiency over the vacuum lamp from one candle per watt to two candles per watt.

The Density of Lead from Radio-active Minerals. T. W. RICHARDS and C. WADSWORTH, 3D. (*The Journal of the American Chemical Society*, vol. xxxviii, No. 2, February, 1916.)—The starting differences observed by several investigators in the atomic weight of lead from radio-active sources obviously suggest that other properties also may vary in different specimens; and the comparison of these may be of service in tracing the true causes of the differences in atomic weight. The phenomena are of interest whether or not one accepts the plausible hypothesis of Soddy and Fajans concerning the "isotopes." In a new field of this sort as great a variety of facts as possible is peculiarly important.

The densities of ordinary lead (having an atomic weight of 207.2) and of lead from Australian radio-active sources (having an atomic weight of 206.3) were carefully determined in a convenient pycnometer which is described in detail for the first time, although long in use. The density of ordinary lead reduced to the vacuum

standard was found to be 11.337, and that of radio-active lead, 11.288. Continued fractionation produced no change in this low density, and it could not have been due to any irregularity in preparing the metal, since the samples were all prepared in the same way. This difference in density is especially interesting because it almost exactly parallels the difference in atomic weight. Thus the atomic volume of radio-active lead is found to be almost exactly equal to that of ordinary lead, the figures being each nearly 18.28.

Turbo Blowers and Compressors. H. L. GUY and P. L. JONES. (*Proceedings of The South Wales Institute of Engineers*, vol. xxxi, No. 5, January 16, 1916.)—Perhaps the most marked feature in the history of power production has been the replacing of reciprocating machinery by that of rotary type. The steam turbine has invaded and captured a considerable portion of the fields of usefulness of the reciprocating steam engine. The centrifugal water-pump has replaced the reciprocating pump; rotary condensed auxiliaries are rapidly superseding reciprocating plant, and rotary air blowers and compressors have entered into successful contest with reciprocating compressors. The principal factors which have decided the issue in favor of the rotary plant are: small space, excellent balance, and low first cost and maintenance. Machinery of this type has the additional and valuable advantage that a mixed pressure turbine can be employed utilizing waste steam, a large quantity of which is usually available.

The turbo blower is really a multi-stage centrifugal air-pump consisting essentially of several pumps driven by a common spindle, with the outlet of one discharging into the intake of the next. Although the operation is very similar to that in a centrifugal water-pump, there are important differences in the two classes of machines. (1) For a given peripheral speed, the terminal pressure is proportional to the density of the medium, hence the pressure produced in the impeller of the blower is about 1/800 of the pressure that would be produced with water, water being 800 times as heavy as air. For this reason it is always necessary to build blowers, even with such low terminal pressures as 5 pounds per square inch, with more than one impeller, and for the more usual pressures of from 8 to 15 pounds per square inch it is necessary to employ three, four, or even five stages. (2) In a water-pump the density remains constant, and therefore the increase in pressure per stage is constant, but in a blower the pressure and temperature of the air change, resulting in a change in density, so that the increase in pressure per stage is continually increasing. Turbo compressors are identical with turbo blowers in principle and operation and usually deliver air at pressures between 50 and 100 pounds per square inch. Stating the efficiency as the ratio of work actually done to that necessary with isothermal compression, an efficiency of 60 to 66 per cent. can be obtained.

Blue Bulb Electric Lamps in Photography. ANON. (*Bulletin Engineering Department, National Lamp Works of General Electric Company*, No. 26, December 30, 1915.)—The short exposure required in portrait and motion-picture photography demands a high intensity of actinic light. At the same time, in order that the reproduction of facial expression may be natural, the brightness of the light should not be so intense as to cause the subject to squint. These contrary requirements led to the development of a special blue-grass bulb for 1000-watt Mazda C. lamps, which is known as the "photographic-blue" bulb. This bulb screens out about two-thirds of the light emitted by a Mazda C. lamp filament, but it transmits, as shown by spectograms, all those rays which are actinic to those green- and yellow-sensitive emulsions that are usually called orthochromatic. Furthermore, the light from the photographic-blue bulb Mazda C. lamp appears like daylight, and its ordinary-emulsion actinicity per candle-power is so nearly equal to that of daylight that it may be mixed with daylight without any allowance being made in judging the proper time of exposure. This is an important quality, for it enables the photographer to estimate amounts of exposure by the brightness of the subject in accordance with his usual practice. Obviously, these advantages, namely, the reduction in brightness and likeness to daylight, can be utilized to the fullest extent with ordinary emulsions, and, since most portrait and motion-picture photographs are made on such emulsions, the photographic-blue bulb is particularly adapted to the illumination of the usual studio.

Peat Powder Used by Sweden for Locomotives. ANON. (*U. S. Commerce Report*, No. 40, February 7, 1916.)—Experiments in the use of peat powder on locomotives of the state railways have demonstrated that as heavy trains can be pulled and as good speed be made where this fuel is employed as where anthracite is used, according to a statement issued by the Swedish Telegram Bureau, which has been received from the secretary of the American Embassy at Stockholm. The statement declares that the powder can technically as well as economically take the place of anthracite as fuel for locomotives.

The railway directors have decided to undertake the development of this class of fuel by two different methods for purposes of comparison. Two experts have been requested to give complete estimates of the cost of preparing a certain bog for the manufacture of peat powder, together with estimates of running expenses, by the respective methods. The bog selected is said to be that at Hasthagen, about one and one-half miles from the station at Vislanda, with an area of about 500 acres.

The Regeneration of Sulphated Storage Cells. G. A. PERLEY and C. W. DAVIS. (*The Journal of Physical Chemistry*, vol. xx,

No. 2, February, 1916.)—The authors have previously shown that sulphated storage cells can be regenerated satisfactorily if the battery acid is replaced by a solution of sodium sulphate. Upon the passage of a normal charging current, the lead sulphate is reduced within sixty hours, even on badly-sulphated grids. This method has since been tried by others with uniformly good results. It was conceivable that some other salt might give deposits that were enough better to justify its use, and, accordingly, some experiments have been made with other sodium salts.

The experiments point to the following general conclusions: (1) Sodium sulphate is the best salt to use in regenerating positive and negative storage-battery grids. (2) Dummy positive grids on the outside of the negative plates diminish the time of reduction. (3) Hydrolysis of the lead salts formed in sodium hydroxide solution yields large and troublesome quantities of lead monoxide. The active material of the grids is removed to a considerable extent. (4) With sodium sulphite solutions, a hard crystalline lead is deposited at the cathode which causes buckling of the grids. (5) Reduction in whole or in part of a sulphated grid results by the use of a solution of sodium sulphate, carbonate, phosphate, or sulphite. (6) Good anode deposits from sulphated grids can be obtained only with sulphate, carbonate, and hydroxide solutions. Relatively high anode corrosion with sodium hydroxide solutions makes these useless.

Ignition of Explosive Gas Mixtures by Electric Sparks. J. D. MORGAN. (*The Journal of the Institution of Electrical Engineers*, vol. 54, No. 254, January 15, 1916.)—A common method of defining the least spark which will ignite a given gas mixture is by specifying the number of volts and ampères, or the number of ampères and the inductance in the circuit prior to the formation of the spark. On the assumption that this gives a measure of the ability of a spark to ignite a gas (or the "incendivity" of the spark), the validity of the method has been rightly questioned. Nevertheless, there is value in the method in indicating the practical conditions under which sparking becomes possible.

An experiment bearing on the subject consists in so adjusting the spark-gap between a pair of pointed poles in the high-tension circuit of an induction coil that in neither air nor coal-gas alone can a spark pass, but the poles emit a faint blue glow or brush discharge visible in the darkness. If the poles are contained in a small chamber into which an explosive coal-gas and air mixture is introduced, it is found that after an interval which varies with the size of the gap the gas explodes. The time can be made to vary from the fraction of a second to as much as two minutes. If the gap is too large, no explosion can be produced; when the explosion-flame appears, a spark at once passes, due to the greater electric conductivity of the ionized gases, and often persists a second or two after the flame has vanished. The

spark appears to be the consequence and not the cause of the explosion.

Experiments such as this suggest the ionic origin of ignition. It has been shown that when a hot wire or spark is the source, ignition only occurs when ionization is produced, and ionization alone without heat has been found to be capable of producing ignition.

The Heat-insulating Properties of Commercial Steam Pipe Coverings. L. B. McMILLAN. (*Proceedings of The American Society of Mechanical Engineers,* December 7 to 10, 1915.)—Most of the early results of tests of the value of steam pipe non-conducting coverings apply at only one temperature or two, at most, and for one or two thicknesses; they are not applicable to modern conditions involving high superheat and thicker coverings.

The work which this paper describes has been carried on for a period of about two years at the University of Wisconsin, and every effort has been made to secure accurate and consistent results. The effect on heat losses of varying the temperature difference between pipe surface and air between 0° and 500° F. has been thoroughly investigated, and the conclusions reached are fully explained. Different thicknesses of material from 0 to 3 inches were tested, and the laws confirmed by the results of these tests permit their application to any thickness whatsoever; and the drop in temperature from steam in a pipe to the inner and outer surfaces of the pipe wall under various conditions may be accurately determined. Another new fact disclosed is that the loss from any covered pipe is a function of the temperature difference between the surface of the covering and the surrounding air; and that this function is the same for all coverings having the same character of surface, regardless of what the other properties of the covering may be, since the effects, if any, of these properties appear in the temperature difference. The value of the function has been determined for canvas-covered surfaces, and a complete explanation of its significance is included.

Kapok—a New Textile Fibre. J. BOYER. (*Scientific American Supplement,* vol. lxxxi, No. 2094, February 19, 1916.)—A French inventor, M. Jean Mondamert de St. René, has just created a new industry in textiles by discovering a method of carding, spinning, and weaving kapok. This is a silky down from the *Bombax ceiba* or *Eriodendron anfractuosum* (silk cotton trees), which are well distributed in the tropics, especially in the West Indies, South America, and the Soudan. At the moment there are fifty establishments in Java collecting this vegetable wool, while five men have been at work with it alone for about a dozen years.

Javanese kapok is composed of threads of a clear yellow, somewhat silky in texture and one-half to three-quarters of an inch in length, and is contained in the long capasudal fruit of the tree. In the midst of the mass of threads constituting a floss there are to be

found, previous to working it, seeds of an inch to an inch and a quarter in diameter, of dark brown color. On examining the floss with a microscope it is seen to be composed of unicellular fibres of the length above given, cylindrical throughout most of the length, and with thin walls and a light skin near the base. The central tube, filled with air, gives to the fibre its very valuable lightness. Aside from their lightness, the fibres of kapok possess absolute impermeability to water, due, according to Dr. Clavel, to the presence of a wax with which the filaments are coated. This is described by M. de St. René as a "solidified oil," who calls attention to the membranous nature of the covering. However this may be, kapok, through its inaptitude to accept water and the quickness with which it dries, does not rot.

It will support from thirty to thirty-five times its weight in water, while ordinary cork will float only about five times its weight. Experiments have shown that a packet of kapok which sustained thirty-two times its weight when first immersed would still hold up twenty-six times its weight at the end of a month in water. No other vegetable substance known has this extraordinary ratio of flotation power and impermeability: it is an attribute of down *Bombax* alone. On account of its elasticity and its lightness, kapok is admirable for the stuffing of cushions or mattresses, replacing advantageously feathers, wool, or hair. Again, its conduct in the water makes it superior for life-preservers, "cork" jackets and other items for life-saving in rivers of the sea.

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